Chapter 7
Abundance and Productivity

Key Questions:

a) *How has the production potential of the population been affected by anthropogenic factors?*
b) *What are the SaSI 2002 status ratings for natural populations of steelhead?*
c) *What are the short-term and long-term trends in the abundance and productivity of naturally-spawning populations of steelhead?*
d) *What have been the temporal trends in smolt-to-adult return rates and how have these trends affected population performance?*
e) *What is the relative extinction risk of each population?*

7.1 Introduction

Abundance and productivity are directly related to sustainable fishing opportunities and population viability. NOAA Fisheries has developed general guidelines for population productivity and abundance to assure population viability (see Box 7-1 and Box 7-2). In this chapter, we assess the abundance and productivity of steelhead populations of Washington by comparing the historical and current production potential, evaluating trends in escapement and smolt-to-adult return rates, and conducting population viability analysis.

Box 7-1. Productivity Guidelines

These general guidelines for assuring that the productivity of a population is consistent with viability were provided in *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). Application of the guidelines requires careful consideration of many population and watershed specific factors.

"1. **A population's natural productivity should be sufficient to maintain its abundance above the viable level.** A population meeting or exceeding abundance criteria for viability should, on average, be able to replace itself. That is, spawner: spawner ratios or cohort-replacement ratios should fluctuate around 1.0 or above. Natural productivity is typically measured as the ratio of naturally produced spawners born in one broodyear to the number of fish spawning in the natural habitat during that broodyear; population abundance estimates at other life-history stages may also be used, provided such estimates span the entire life cycle (e.g., smolt to smolt estimates).

2. **A viable salmonid population that includes naturally spawning hatchery fish should exhibit sufficient productivity from naturally-produced spawners to maintain population abundance at or above viability thresholds in the absence of hatchery subsidy.** In a strict sense, this guideline suggests that the mean Natural Return Ratio (NRR) for a viable population should fluctuate around 1.0, indicating negligible hatchery influence on the population. In a practical sense, the requirement that a viable population be demographically independent of a hatchery population suggests that a viable population's mean NRR not be less than approximately 0.9, but this estimate neglects other issues related to the influence of hatchery fish on natural production. A viable population should not exhibit a trend of proportionally increasing contributions from naturally spawning hatchery fish.

3. **A viable salmonid population should exhibit sufficient productivity during freshwater lifehistory stages to maintain its abundance at or above viable thresholds—even during poor ocean conditions.** A population's productivity should allow it both to exploit available habitat and exhibit a compensatory response at low population sizes. When spawner abundance is below the long-term mean, there should be a corresponding increase in per capita smolt production, even though such an increase may not suffice to offset declines in marine survival.

4. **A viable salmonid population should not exhibit sustained declines in abundance that span multiple generations and affect multiple broodyear-cycles.** "Sustained" declines are those that continue longer than the typical lag in response associated with a population's generation time. Thus, sustained declines differ from rapid transitions between one stable level and another (e.g., changes in abundance related to large-scale, low frequency environmental forcing such as those related to oceanic regime shifts). They also differ from short-term, severe perturbations in abundance, such as those related to strong El Niño events that are followed by relatively rapid recovery.

Box 7-1. Productivity Guidelines (continued)

5. **A viable salmonid population should not exhibit trends or shifts in traits that portend declines in population growth rate.** Changes in such traits, such as size and age of spawners, that affect population growth rate are often more easily and precisely quantified than are changes in abundance and thus, may provide earlier indication of declining population growth rate. For example, reduced size of mature individuals in a population may indicate reduced fecundity, lessened ability to reach spawning grounds, a decreased capacity for constructing redds that are deep enough to resist bed scour, or other factors that contribute to reduced production of offspring. Likewise, increasing age-at return may reduce a population's intrinsic productivity by exposing adults to greater pre-reproductive spawning risk.

6. **Population status evaluations should take into account uncertainty in estimates of population growth rate and productivity-related parameters.** To estimate long-term trends and spawner-recruit ratios, it is important to have an adequate time series of abundance. Unfortunately, such time series, when they exist at all, are often short, contain large observational errors, or both. These constraints may greatly limit the power of statistical analyses to detect ecologically significant trends before substantial changes in abundance have occurred.

Box 7-2. Abundance Guidelines

These general guidelines for assuring that the abundance of a population is consistent with viability were provided in *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). Application of the guidelines requires careful consideration of many population and watershed specific factors.

"1. **A population should be large enough to have a high probability of surviving environmental variation of the patterns and magnitudes observed in the past and expected in the future.** Sources of such variation include fluctuations in ocean conditions and local disturbances such as contaminant spills or landslides. Environmental variation and catastrophes are the primary risks for larger populations with positive long-term average growth rates.

2. **A population should have sufficient abundance for compensatory processes to provide resilience to environmental and anthropogenic perturbation.** In effect, this means that abundance is substantially above levels where depensatory processes are likely to be important and in the realm where compensation is substantially reducing productivity. This level is difficult to determine with any precision without high quality long-term data on population abundance and productivity, but can be approximated by a variety of methods.

3. **A population should be sufficiently large to maintain its genetic diversity over the long term.** Small populations are subject to various genetic problems, including loss of genetic variation, inbreeding depression, and deleterious mutation accumulation, that are influenced more by effective population size than by absolute abundance.

4. **A population should be sufficiently abundant to provide important ecological functions throughout its life-cycle.** Salmonids modify both their physical and biological environments in various ways throughout their life cycle. These modifications can benefit salmonid production and improve habitat conditions for other organisms as well. The abundance levels required for these effects depend largely on the local habitat structure and particular species' biology.

5. **Population status evaluations should take uncertainty regarding abundance into account.** Fish abundance estimates always contain observational error, and therefore population targets may need to be much larger than the desired population size in order to be confident that the guideline is actually met. In addition, salmon are short-lived species with wide year-to-year abundance variations that contribute to uncertainty about average abundance and trends. For these reasons, it would not be prudent to base abundance criteria on a single high or low observation. To be considered a VSP, a population should exceed these criteria on average over a period of time.

7.2 Methods

7.2.1 Historical and Current Production Potential

We used predictions from the Ecosystem Diagnosis and Treatment (EDT) model (see Box 7-3) (Mobrand et al. 1997) to compare the equilibrium abundance of populations under environmental conditions that existed prior to European settlement ("pre-settlement") and currently. The EDT model relates characteristics of aquatic habitat to life-stage specific estimates of population productivity and capacity. Stage specific estimates are linked using the recursion formula of Mousalli and Hillborn (1986) to define a Beverton-Holt stock production function:

$$R = \frac{aS}{1 + aS/b},$$

where S is the number of spawners, R is the adult recruitment, a is intrinsic productivity, and b is the carrying capacity. The equilibrium abundance (N_{eq}), or production potential, is the number of spawners that would occur in the absence of fishing harvest and is computed as:

$$N_{eq} = b(1 - \frac{1}{a}).$$

Changes in both the intrinsic productivity and carrying capacity affect the equilibrium abundance.

7.2.2 SaSI Status and Short Term Abundance Trends

In Washington, salmonid stocks are identified and rated healthy, depressed, critical, unknown or extinct in the Salmonid Stock Inventory (WDF et al. 1993; WDFW 2003). Healthy status means that production (generally based on some measure of abundance such as spawner escapement, sport harvest, or juvenile counts) is consistent with the habitat (or goals for the stock), and is within the natural variation for the stock. Depressed status means that production is lower than expected, but not so low that permanent genetic damage to the stock is likely. Critical status means that production is so low that permanent damage to the stock is likely or has already occurred. Unknown status reflects insufficient abundance data used to adequately rate status (e.g. escapement is not monitored). The status of some SaSI stocks, including Deschutes steelhead, was not rated in 2002 because WDFW and tribal biologists

Box 7-3. Ecosystem Diagnosis and Treatment Model

McConnaha (2000) described the Ecosystem Diagnosis and Treatment (EDT) model as "an analytical tool relating habitat features and biological performance to support fish and wildlife planning. It captures a wide range of information and makes it accessible to planners, decision-makers and scientists as a working hypothesis of the ecosystem. EDT acts as an analytical framework that brings together information from empirical observation, local experts, other models and analysis.

EDT differs from models often used in fish and wildlife management and offers important features that can augment conventional methods. EDT is best described as a scientific model (see Hilborn and Mangel, *The Ecological Detective*). A scientific model attempts to explain the mechanisms behind phenomenon to form an overall hypothesis. This contrasts with more conventional statistical models. These provide correlation-based predictions of events without necessarily explaining the underlying mechanism. As a scientific model, EDT constructs a working hypothesis of a subbasin as a basis for planning and for comparison of alternative futures. This hypothesis provides measurable metrics to gauge progress and testable hypotheses to refine knowledge. EDT helps us understand and describe the inevitable complexity of ecological systems in order to plan effective recovery strategies. A statistical model, on the other hand, seeks to reduce complexity to a small number of predictive or correlated variables. A scientific model like EDT provides the hypothesis while a statistical model can provide the test.

The premise of EDT is simple: habitat forms the template for biological performance. Species perceive habitat based on their genetically based potential. The result is species abundance, productivity, diversity and population structure. Although EDT can become complicated due to the fine-scale complexity of its ecological description, it important to bear in mind the underlying simplicity of its premise.

EDT has two major components: a detailed description of the habitat and a set of rules or hypotheses that define an understanding of how a species perceives or responds to that habitat. Habitat units are defined as stream segments based on gradient and stream network. Environmental conditions in each habitat unit are described by 46 attributes that collectively define our understanding of how fish perceive their surroundings. The rules estimate life stage productivities and capacities in the form of the Beverton-Holt relationship. Integrating over a life history trajectory provides population abundance, productivity and diversity.

The environmental attributes and rules in EDT provide, respectively, monitoring attributes and research hypotheses. This provides a framework for accountability, monitoring and research. The environmental description and rules within EDT can be developed and tested through a variety statistical models and research. In this way, EDT presents a scientifically based framework for natural resources planning and action."

concluded that no significant natural production occured, and the presence of small numbers of spawners resulted primarily from the annual returns of first-generation hatchery fish.

Steelhead SaSI status is assessed by local WDFW and tribal biologists who examine abundance data (escapement, harvest, juvenile counts, etc.). If no marked negative trend in abundance is seen, escapement goals are generally being met, and abundance is consistent with the available habitat, the stock is rated Healthy. If a negative trend in abundance is evident, and/or stock abundance falls consistently below the goal for the stock, or if the stock performs below that level expected given the habitat potential available, then stock status is rated depressed or critical. Depressed or critical ratings are made subjectively depending on the condition of the stock. Resident phenotypes were not included in the assessment because information is generally lacking on the abundance and reproductive interactions of resident and anadromous *O. mykiss* in Washington.

We also compared the average abundance of steelhead in 1999 through 2004 relative to 1994 through 1998 to provide a short-term assessment of population performance. In contrast to the SaSI ratings, this assessment is sensitive to annual management actions (e.g., fishery harvest rates, passage) and environmental factors (e.g., flooding, marine survival). The abundance of populations was characterized as increasing, decreasing, or unchanged, where the latter was defined as 10 fish or less difference in the average abundance in the two time periods.

7.2.3 Smolt-to-Adult Return

Estimates of smolt-to-adult return (SAR) rates can often be useful in interpreting observed trends in escapement or recruits per spawners. Since a SAR measure survival from the smolt stage to adult return, it is entirely independent of freshwater survival factors like spawner density and incubation conditions. Trends that are observed reflect factors that act during smolt outmigration and marine residence. Since many populations from a geographic region may have a similar marine distribution, indices from a subset of populations can often help explain survival trends that are occurring on a large geographic scale. Estimates of SAR rates from natural-origin stocks are of the greatest value because they directly measure the attribute of interest. However, estimating the natural steelhead smolt production from watersheds can be difficult and expensive. In the absence of estimates of the natural production of smolts and the subsequent return of adults, SAR indices obtained from the release of hatchery-origin smolts can be used as a surrogate. To avoid confounding the effects of hatchery practices and marine survival conditions, hatchery practices should remain as consistent as possible.

We attempted to select hatchery programs with consistent rearing methods and where estimates of the escapement were available. However, in most cases, the SAR estimates are indices rather than survival rates since not all returning fish are enumerated. This inevitably will underestimate the SAR for smolts released from hatchery programs. The selected programs are summarized briefly below:

Skagit Winter Hatchery, Quinault Winter Hatchery, Humptulips Winter Hatchery. A SAR index was estimated for each year by dividing the total return (recreational catch, commercial catch, and escapement) of hatchery-origin adults by the total number of smolts released two years previously. This is a SAR index because the escapement of all returning hatchery-origin adults is not enumerated and not all hatchery-origin steelhead return after two summers in marine waters.

Elochoman Winter Hatchery, Washougal Winter Hatchery, Washougal Summer Hatchery. A SAR index was estimated for each year by dividing the total return (recreational catch and hatchery rack escapement) of hatchery-origin adults by the total number of smolts released two years previously. This is a SAR index because the escapement of all returning hatchery-origin adults is not enumerated and not all hatchery-origin steelhead return after two summers in marine waters.

Elwha Winter. A SAR index was estimated for each year by dividing the total return (recreational and commercial catch of natural and hatchery-origin steelhead, and hatchery rack escapement) by the total number of smolts released two years previously. This is an index because the catch includes some fish of natural-origin, all adults do not return after two summers in marine waters, and the escapement of all returning hatchery-origin adults is not enumerated.

Puyallup Winter Hatchery, Quillayute Winter Hatchery. A SAR index was estimated for each year by dividing the total return (recreational catch, commercial catch, hatchery rack return, and number of hatchery-origin adults spawning in the river) by the number of smolts released two years previously. This is a SAR index because the escapement of all returning hatchery-origin adults is not enumerated and not all hatchery-origin steelhead return after two summers in marine waters.

Kalama Winter Hatchery, Kalama Summer Hatchery. A SAR index was estimated for each year by dividing the total return (recreational catch and hatchery rack escapement) of hatchery-origin adults by the total number of smolts released two years previously. Allocation of catch between summer and winter steelhead for the return years 1976/77 through 1995/96 based on examination of fish at the Kalama Falls trap. Allocation of catch subsequent to 1995/96 based on WDFW catch accounting periods.

Wells Hatchery. A SAR index was estimated for each brood year by dividing the brood return in multiple years to Wells Dam by the number of smolts released in the brood year (WDFW 2002; C. Snow, pers. comm.).

Lyons Ferry Hatchery, Touchet Acclimation Pond. A SAR index was estimated for each brood year by adding the estimated total number of CWT recoveries in catch and escapement by the number of CWTs released (WDFW 2005a).

For some analyses a standardized SAR index was computed by dividing the SAR index by the average SAR index for smolts entering the ocean in the years 1992 through 1995. This was the first four-year period for which a SAR index was available for each of the release locations.

7.2.4 Population Viability Analysis

Steelhead abundance varies in response to freshwater or marine survival, harvest mortality, and the effects of hatchery programs. Often productivity or survival cannot be measured directly, however changes in recruitment or escapement can inform managers about population trends and consequently about extinction risk. Population viability analysis (PVA) is one method that can be used to estimate the rates of change in steelhead abundance and the probability of extinction.

Dennis et al. (1991) proposed an approach for PVA that has been broadly applied and refined for application to salmonid populations. Dennis et al. noted that the survival or extinction of a population is inherently stochastic and developed a rigorous statistical model for estimating growth rates and extinction risk. The stochastic exponential growth model includes one parameter to describe the underlying growth rate of the population and a second to capture annual variation resulting from process error. Process error is variability associated with natural processes (i.e., environmental conditions) and contrasts with measurement error, or errors associated with inaccurate measurement of variables.

Application of the methods of Dennis et al. (1991) to estimate variation in the growth rate may result in estimates of extinction that are biased high if measurement error exists in the observed data. Confounding of measurement error and process error will often result in an estimate of annual variation that is positively biased. In an attempt to separate out the process error, Holmes and Fagan (2002) proposed an alternative approach that they concluded improved the estimation of process error, however, they acknowledged their approach was biased. More recently, Staples et al. (2004) refined the Dennis et al. (1991) method by including appropriate covariance terms, which provided information to separate the process from the measurement error, and resulted in producing unbiased estimates of process error.

We used the population viability analysis of Staples et al. (2004) to estimate trends in wild abundance for 83 populations in Washington State because it provides the ability to estimate both measurement and process error. Data used to quantify trends in wild steelhead populations with the PVA model consist of annual measures of escapement and/or total run size (i.e., escapement plus harvest). Annual measures of mature steelhead in freshwater do not include other important population components such as the large, immature fish still in marine waters or juveniles in freshwater that have yet to migrate to sea. The sum total of all these components comprises a populations abundance at any given point in time, hence the measures used represent a subset of the total population. But as Dennis et al. (1991) point out, the model's properties are flexible enough so that generally any linear combination of age or stage classes will fulfill the assumptions (e.g., Dennis et. al. 1991 applied it to counts of adult female grizzly bears). Results of the PVA analysis for each population presented in this section should be approached with caution. Populations of particular interest can and should include more site-specific data for a complete analysis, e.g. age composition, resident phenotype influence, and/or habitat parameters.

We chose to limit analyses to those populations with at least estimates of escapement since this portion of the mature run usually constitutes a sizeable fraction, frequently the largest component, of the total mature run. We considered trends for populations with only estimated sport catch as likely to be much more inaccurate.

Using the method of Staples et al. (2004) to estimate trend and process error, we used the estimator for extinction probabilities from Dennis et al. (1991). For these calculations, we defined a quasi extinction level as an escapement estimate of 63 spawners or less, and estimated the probability of arriving at this number in t years for each population:

$$P[T \le t] = \Phi\left(\frac{-x_d + |\hat{\mu}|t}{\hat{\tau}\sqrt{t}}\right) + e^{\frac{2x_d|\hat{\mu}|}{\hat{\tau}^2}}\Phi\left(\frac{-x_d - |\hat{\mu}|t}{\hat{\tau}\sqrt{t}}\right),$$

where $x_d = \ln\left(\frac{63}{\hat{N}_{last}}\right)$;

T = time to extinction;

$\hat{N}_{last}$ = last observed abundance;

$\hat{\mu}$ = estimate of the instantaneous rate of change;

$\hat{\tau}^2$ = estimated process error variance;

Φ = the Normal cumulative distribution function,

t = years.

The quasi extinction level was derived from a threshold of an effective populations size of 50 to minimize the loss of diversity associated with random genetic effects at small population sizes (Frankel and Soule 1981; Nelson and Soule 1987). The ratio of effective population size to census population (N_c) was assumed to be 0.20, and the average generation length was assumed to be four years. The number of census spawners to achieve a per generation effective population size of 50 is then given by:

$$N_c = \frac{50}{(0.20)(4)}$$

All populations with a declining abundance, or a last observed abundance less than 63 will have an extinction probability equal to 1. Hence, the probability is more accurately interpreted as the conditional probability of reaching the extinction threshold of 63 in 100 years given an estimate of a non-decreasing population. The probability $\pi\left(x_d, \mu, \sigma^2\right)$ that the extinction threshold is attained is

$$\pi\left(x_d, \mu, \sigma^2\right) = \begin{cases} 1, \ \mu \le 0 \\ e^{\frac{-2\mu x_d}{\sigma^2}}, \mu > 0. \end{cases}$$

Confidence intervals for extinction probabilities were estimated using parametric bootstrap methods, for a $\hat{\mu} \sim N\left(\hat{\mu}, \tau^2 / n\right)$, where n is the number of log-ratios of abundance in the data set, and a process error, τ^2 with a chi-square distribution of

$$\frac{\hat{\tau}^2}{n} \cdot \chi^2_{n-3}.$$

Viability results were categorized using the methods of Allendorf et al. (1997). Risks or extinction were categorized as Very High if the population had at least a 50% probability of extinction in 5 years; High if the population had a risk of extinction of 20% within 20 years; 3) Moderate if the population had a risk of extinction of 5% within 100 years; and 4) Low if the populations had a risk of extinction of less than 5% within 100 years.

7.3 Results

7.3.1 Puget Sound

Synopsis. A substantial decline in the abundance of the anadromous form of O. mykiss has occurred in many rivers in Puget Sound during the last 20 years. The 2002 SaSI status assessment rated 5 (20%) populations as Healthy, 19 as Depressed (76%), and 1 (4%) as Critical. The decline in abundance likely linked, at least in part, with reductions in smolt-to-adult return (SAR) rates. The average SAR index for hatchery smolts released in the Puget Sound region declined from a peak of 7.0% for smolts entering the ocean in 1983 to 0.2% in 1996 and has remained low since that time. Population viability analysis was used to assess the relative risk of extinction of populations of winter steelhead. Of the 14 populations assessed, 4 (29%) were assessed with a relatively High risk of extinction and 3 (21%) with a Very High risk of extinction. Extinction risk may be biased high for some populations because resident O. mykiss were not explicitly considered in the population viability analysis. On March 26, 2006, NOAA Fisheries proposed listing the Puget Sound DPS as Threatened under the ESA (71 FR 15666)

ESA Status

NOAA Fisheries proposed listing the Puget Sound DPS as Threatened under the ESA on March 26, 2006 (71 FR 15666). A NOAA Biological Review Team reviewed the status of the ESU in 2005 (NMFS 2005). The scores for overall risk category ranged from “neither at risk of extinction nor likely to become so” to “at risk of extinction” in the foreseeable future. However, a majority of the team supported a conclusion that steelhead in the Puget Sound ESU are likely to become at risk of extinction in the future – but are not currently in danger of extinction.

Pre-Settlement and Current Production Potential

The production potential is the average number of spawners expected in the absence of fishing. Comparing the pre-settlement and current production potential provides an assessment of how anthropogenic induced changes have affected the ability of the population to support fisheries and maintain abundance and productivity consistent with a viable population.

The Nisqually Winter population is currently the only population of steelhead in the Puget Sound region for which predictions of historical and current production potential are available. The predicted current production potential of 2,130 is 57% less than the predicted historical production potential of 4,939 (J. Dorner, pers. comm.).

Status and Short-Term Abundance Trend

The 2002 SaSI status assessment rated 20% of the populations as Healthy, 76% as Depressed, and 4% (1 population) as Critical (see Appendix 7-A for population specific assessments). The one critical population, Lake Washington, had an escapement of less than 50 fish in each year from 2000 through 2004. However, resident *O. mykiss* are abundant within this watershed (Fleishcher 2005). The five Healthy populations are distributed throughout the Puget Sound ESU: 1) Samish Winter; 2) South Fork Skykomish Summer; 3) Tolt Summer; 4) Green Winter; and 5) Discovery Bay Winter. A status assessment could not be completed for 27 populations (52%) because of insufficient data.

Table 7-1. Status of steelhead populations in the Puget Sound region.

Run timing	Number of Populations	Populations with unknown status	Populations with known status			
			Number	Healthy (%)	Depressed (%)	Critical (%)
Summer	16	12	4	2 (50%)	2 (50%)	0 (0%)
Winter	36	15	21	3 (14%)	17 (81%)	1 (5%)
All	52	27	25	5 (20%)	19 (76%)	1 (4%)

A decline in abundance in recent years is generally evident from the analysis of short-term trends in escapement (Table 7-1 and Fig. 7-1)(see Appendix 7-A for population specific assessments). Only 21% of the populations had an increase in the average escapement from 1999 through 2004 relative to the period 1994 through 1998; 67% of the populations had a reduction in the average escapement. Greatest reductions were evident for the Carbon Winter (-50%), Pilchuck Winter (-51%), Snohomish/Skykomish Winter (-55%), and Lake Washington Winter (-79%) winter populations. The average escapement of the Hamma Hamma Winter population increased by more than 300% as the result of a artificial production program. Excluding the Hamma Hamma population, escapements decreased by an average of 23% in 1999 through 2004 relative to the prior five years.

The Nooksack River is the only major river system in this region lacking a historical time series of escapement data. Surveys conducted in this basin in 2003-2004 indicated that a substantial winter steelhead population may exist, with a estimated escapement of over 1,500 spawners.

Table 7-2. Short-term trend in escapement for steelhead populations in the Puget Sound region. Base years are 1994 through 1998; years for comparison are 1999 through 2004.

Run timing	Number of populations	Populations without spawner data	Populations with spawner data			
			Number	Increasing (%)	Unchanged (%)	Decreasing (%)
Summer	16	12	4	1 (25%)	1 (25%)	2 (50%)
Winter	36	17	20	4 (20%)	2 (10%)	14 (70%)
All	52	29	24	5 (21%)	3 (12%)	16 (67%)

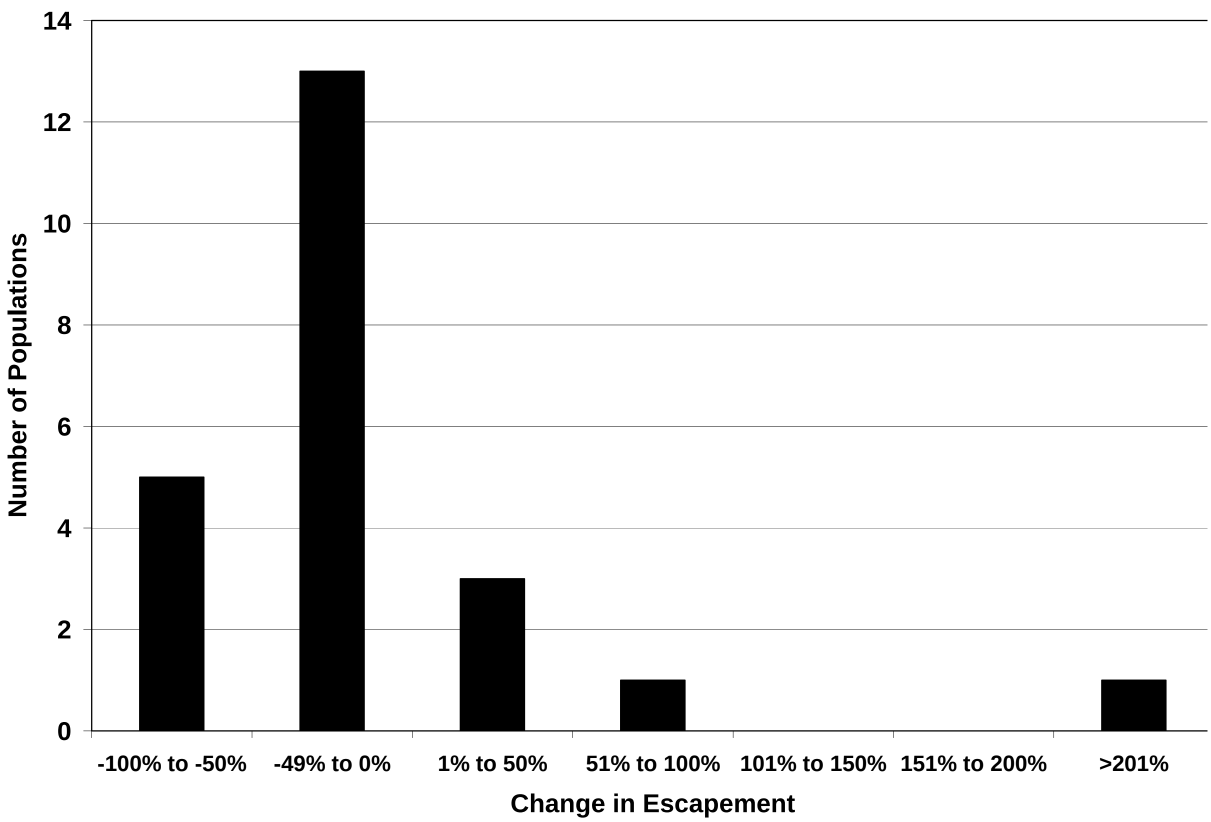

Figure 7-1. Change in the average escapement for populations of steelhead in the Puget Sound region in 1999 through 2004 relative to the average escapement in 1993 through 1998.

Smolt-to-Adult-Return

Indices for the smolt-to-adult return (SAR) rate were estimated for hatchery releases of winter steelhead into the Skagit River, the Puyallup River, and the Elwha River (Fig. 7-2). All three rivers showed a similar pattern with the largest SAR indices occurring for smolts entering the ocean in 1983. The average SAR index declined from a peak of 7.0% for smolts entering the ocean in 1983 to 0.2% in 1996. The average SAR index has remained at a low level since that time, ranging from 0.2% to 0.5% for hatchery smolts entering the ocean in the period from 1997 through 2002.

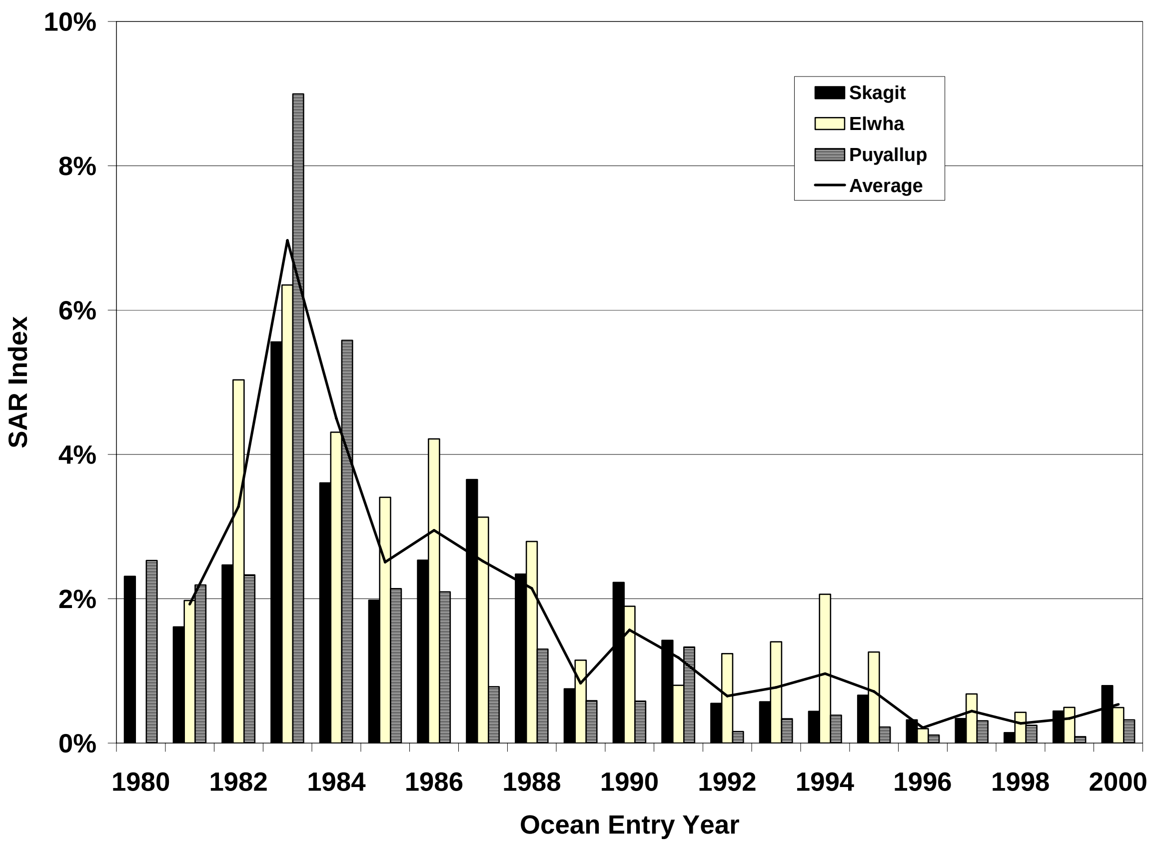

Figure 7-2. SAR indices for hatchery-origin winter steelhead smolts released into the Skagit, Elwha, and Puyallup rivers.

Population Viability Analysis

Population viability analyses are critically dependent upon correctly identifying population structure. Uncertainty in our understanding of population structure is higher in the Puget Sound region because a systematic review has not been recently conducted (see Chapter 5, Population Identification). The results from the population viability analysis described below should be considered preliminary until that review is completed.

The population growth rate could be estimated for 20 populations with a time series of at least 8 years of escapement data or indices of escapement (Table 7-3). A negative population growth rate was estimated for 12 (60%) of the populations. Five populations had p-values of less than or equal to 0.11 for a statistical test of the null hypothesis that the growth rate was nonnegative. These populations were distributed throughout the Puget Sound ESU: 1) the Stillaguamish Winter population in North Puget Sound; 2) the Carbon Winter and Nisqually Winter populations in South Puget Sound; 3) the Skokomish Winter population in Hood Canal; and 4) the Morse Creek-Independents population in the Strait of Juan de Fuca.

Population viability analysis was used to assess the relative risk of extinction for each population with a times series of at least 8 years of escapement data. Confidence intervals of the risk of extinction were generally wide at the 20 and 100-year time horizons (see Appendix 7-B) which suggests that the results should be used with caution and only to broadly assess the relative extinction risk of the populations. Of the 14 populations assessed, 7 (50%) were characterized with a relatively Low risk of extinction, 4 (29%) with a relatively High risk, and 3 (21%) with a Very High risk of extinction (Table 7-3). None of the populations with a relatively High or Very high risk of extinction were located in North Puget Sound, while 2 of the 3 populations with a Very High risk of extinction (Lake Washington Winter and Mainstem Puyallup Winter) are located in South Puget Sound.

All of the population viability analyses were conducted under the assumption that only anadromous spawners contribute to the abundance of each population. This assumption may result in estimates of extinction risk that are too high because the presence of resident forms of *O. mykiss* may reduce the likelihood of extinction. Perhaps the most extensive data exists for resident *O. mykiss* in the Cedar River. The abundance of resident fish of greater than 200 mm fork length in 2003 was estimated as 17,468 fish, or approximately 800 fish per mile (Fleischer 2005).

Table 7-3. Growth rate, p-value for statistical test ($H_0 : \mu \geq 0$), estimated process error ($\hat{\tau}^2$), and relative risk of extinction for populations of steelhead in the Puget Sound region.

Population	Last Escapement	Growth Rate		$\hat{\tau}^2$	Relative risk
		Estimate	p-value		
Samish Winter	930	+0.06	0.69	0.33	Low
Skagit Winter	7,332	+0.01	0.63	0.04	Low
Stillaguamish Winter	[1]	-0.07	<0.01	<0.01	[1]
Snohomish-Skykomish Winter	2,188	+0.02	0.63	0.10	Low
Pilchuck Winter	1,336	+0.04	0.68	0.19	Low
Tolt Summer	[1]	-0.05	0.32	0.20	[1]
Snoqualmie Winter	708	-0.03	0.26	0.03	Low
Lake Washington Winter	44	-0.16	0.16	0.54	Very High
Green Winter	2,383	+0.02	0.70	0.03	Low
Mainstem Puyallup Winter	91	-0.06	0.16	0.07	Very High
White (Puyallup) Winter	184	-0.01	0.43	0.14	High
Carbon Winter	410	-0.07	0.02	0.02	High
Nisqually Winter	730	-0.07	0.02	0.02	High
Dewatto Winter	[1]	-0.01	0.37	<0.01	[1]
Tahuya Winter	[1]	+0.01	0.58	0.10	[1]
Skokomish Winter	223	-0.08	<0.01	<0.01	High
Dosewallips Winter	[1]	+0.03	0.79	<0.01	[1]
Duckabush Winter	[1]	+0.02	0.57	<0.01	[1]
Discovery Bay Winter	40	-0.03	0.29	0.08	Very High
Morse Creek-Independents Winter	121	-0.01	0.11	0.01	Low

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.

7.3.2 Olympic Peninsula

Synopsis. Populations of winter steelhead in the Olympic Peninsula region were generally rated as Healthy in the 2002 SaSI assessment. Only one population, Lower Quinault/Quinault Lake Winter, was rated as Depressed and no populations were rated as Critical. Short-term trends in escapement are also generally positive for winter steelhead in the Olympic Peninsula region. Average escapement increased in 1999 through 2004 relative to the prior five years for eight populations (62%) and decreased in only three populations. Smolt-to-adult return (SAR) rates have declined from the peak levels observed in the early 1980s, but remain on average at the highest level (approximately 4%) of any region in the state. Population viability analysis indicated that the relative risk of extinction was Low for all populations with the exception of Salt Creek Winter.

ESA Status

Populations of steelhead in the Olympic Peninsula ESU are not listed under the ESA.

Pre-Settlement and Current Production Potential

Predictions of pre-settlement and current production potential are not available for any populations of steelhead in the Olympic Peninsula region.

SaSI Assessment and Short-Term Trends

Populations of winter steelhead in the Olympic Peninsula region were generally rated as Healthy in the 2002 SaSI assessment (Table 7-4) (see Appendix 7-A for population specific assessments). Only one population, Lower Quinault/Quinault Lake Winter, was rated as Depressed and no populations were rated as Critical. However, status assessments were not possible for 52% of the populations of any run timing, and no status assessments were possible for summer steelhead.

Short-term trends in escapement were also generally positive for winter steelhead in the Olympic Peninsula region (Table 7-5 and Fig. 7-3)(see Appendix 7-A for population specific assessments). Average escapement increased in 1999 through 2004 relative to the prior five years for eight populations (62%) and decreased in only three populations. In two of the three latter populations (Sol Duc Winter and Hoh Winter), the average escapement remained greater than the escapement goal. Escapements increased by an average of 4% in 1999 through 2004 relative to the prior five years for populations in the Olympic Peninsula region.

Table 7-4. Status of steelhead populations in the Olympic Peninsula region.

Run timing	Number of Populations	Populations with unknown status	Populations with known status			
			Number	Healthy (%)	Depressed (%)	Critical (%)
Summer	7	7	0	NA	NA	NA
Winter	24	11	13	12 (92%)	1 (8%)	0 (0%)
All	31	18	13	12 (92%)	1 (8%)	0 (0%)

Table 7-5. Short-term trend in escapement for steelhead populations in the Olympic Peninsula region. Base years are 1994 through 1998; years for comparison are 1999 through 2004.

Run timing	Number of Populations	Populations without spawner data	Populations with spawner data			
			Number	Increasing (%)	Unchanged (%)	Decreasing (%)
Summer	7	7	0	NA	NA	NA
Winter	24	11	13	8 (62%)	2 (15%)	3 (23%)
All	31	18	13	8 (62%)	2 (15%)	3 (23%)

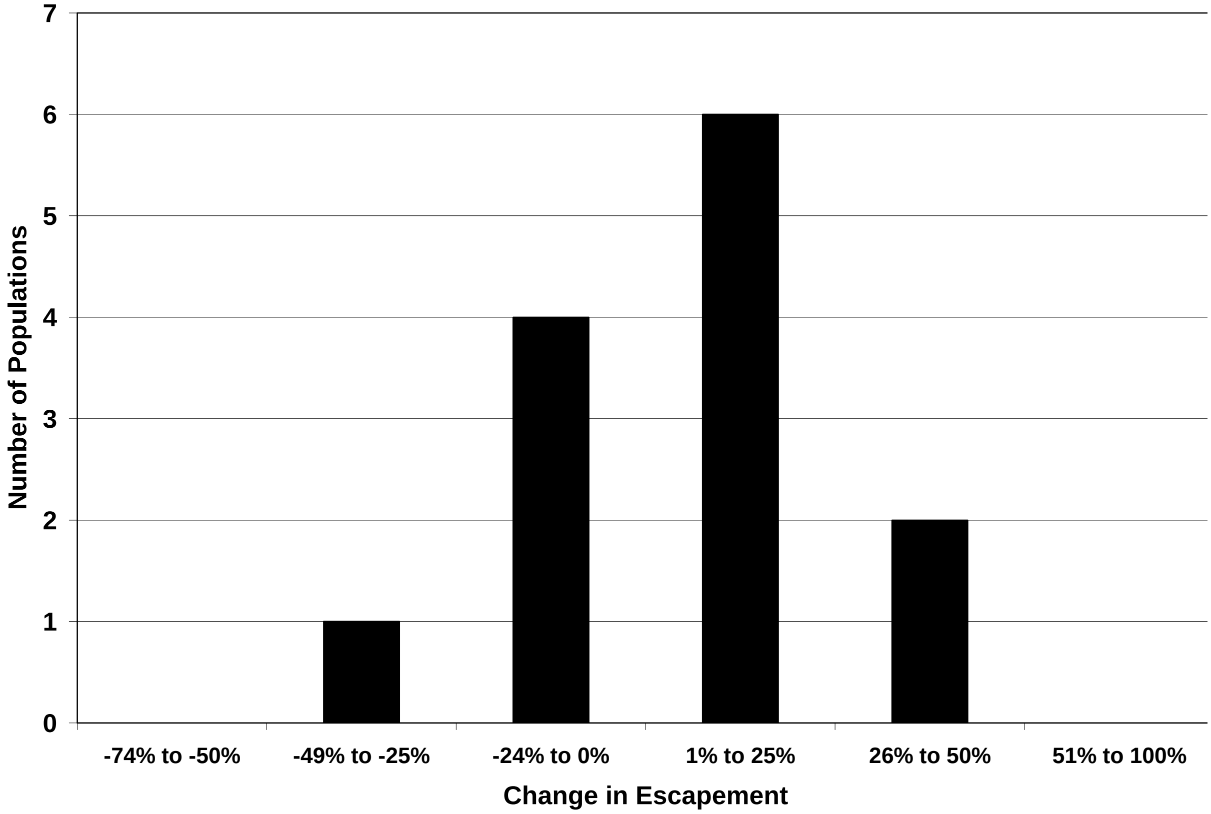

Figure 7-3. Change in the average escapement for populations of steelhead in the Olympic Peninsula region in 1999 through 2004 relative to the average escapement in 1993 through 1998.

<u>Smolt-to-Adult Return</u>

Smolt-to-adult return (SAR) indices were computed for hatchery-origin winter steelhead released into the Quinault and Quillayute rivers (Fig. 7-4). The average SAR indices for the Olympic Peninsula can be grouped into three general categories: 1) smolts entering the ocean from 1977 through 1981 had an average SAR index of approximately 6%; 2) 1982 though 1987 were characterized by SAR indices of approximately 8%-12%; and 3) 1989 through 2001 were characterized by SAR indices of approximately 4%.

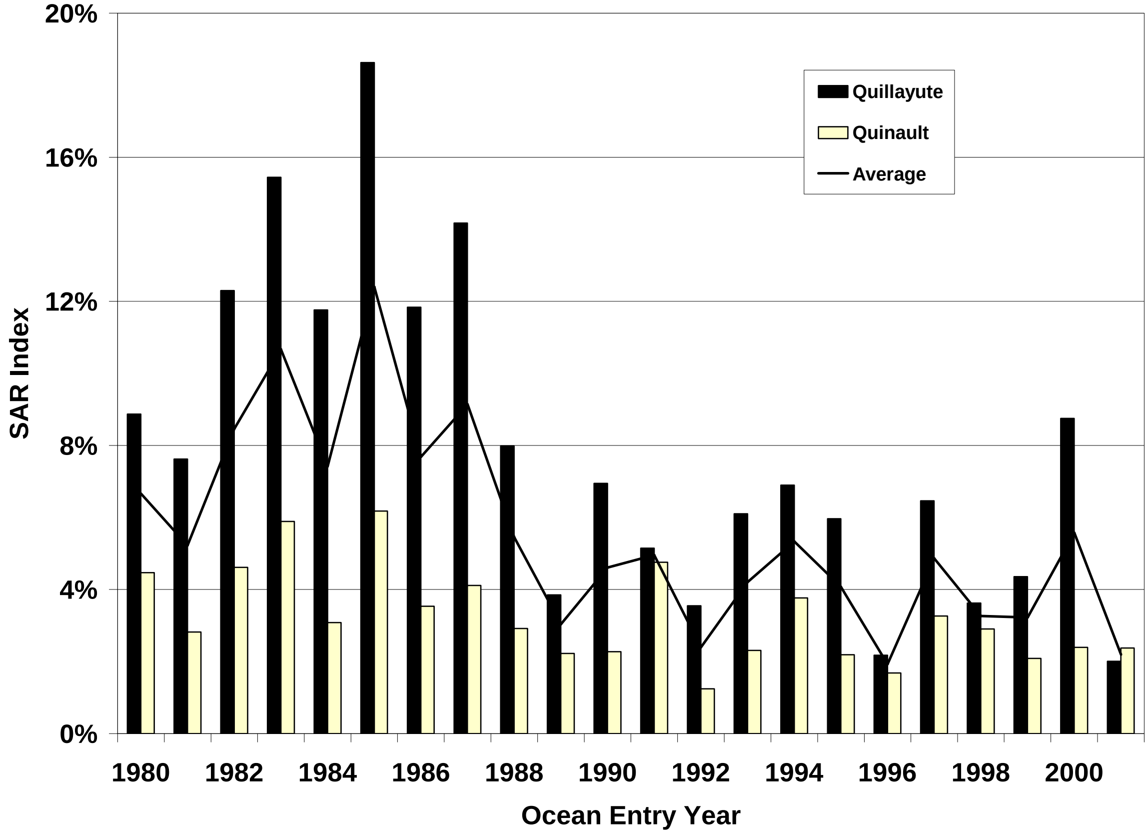

Figure 7-4. SAR indices for hatchery-origin winter steelhead smolts released into the Quillayute and Quinaut rivers.

Population Viability Analysis

Population viability analyses are critically dependent upon correctly identifying population structure. Uncertainty in our understanding of populations structure is higher in the Olympic Peninsula because a systematic review has not been recently conducted (see Chapter 5, Population Identification). The results from the population viability analysis described below should be considered preliminary until that review is completed.

The estimated population growth rate was positive for seven populations and negative for four populations (Table 7-6). A test of the null hypothesis that the growth rate was greater than or equal to 0 was rejected an $\alpha \leq 0.10$ for only the Salt Creek Winter population. The significance of this result is uncertain because the estimated escapement has exceeded the escapement goal in 6 of the last 10 years, including the final year of the time series of data.

The negative population growth rates estimated for the Hoko Winter, Dickey Winter, and Hoh Winter population are not a conservation concern. All populations remain within or above the normal range of variation about escapement goals that have been established by the comanagers:

1) The estimated escapement of the Hoko Winter population in 2004 was 747 winter steelhead with an escapement goal of 400.
2) The Dickey Winter population is part of the Quillayute River management unit. The escapement for the Quillayute River in 2004 was 11,464 relative to an escapement goal of 5,900. Of the 5,900 fish escapement goal for the Quillayute River, the Dickey Winter population component is 123 fish. The estimated escapement of the Dickey Winter population has exceeded 123 fish in every year since 1986.
3) The estimated escapement of the Hoh Winter population in 2004 was 2,268 winter steelhead with an escapement goal of 2,400.

Population viability analysis indicated that the risk of extinction was relatively Low for all populations with the exception of the Salt Creek population. Risk of extinction for the Salt Creek Winter population was rated as Moderate because of the estimated negative growth rate and the relatively small size of the population.

Table 7-6. Growth rate, p-value for statistical test ($H_0 : \mu \geq 0$), estimated process error ($\hat{\tau}^2$), and relative risk of extinction for populations of steelhead in the Puget Sound region.

Population	Last Escapement	Growth Rate		$\hat{\tau}^2$	Relative risk
		Estimate	p-value		
Salt Creek-Independents Winter	170	-0.04	0.07	<0.01	Moderate
Pysht-Independents Winter	367	+0.01	0.57	0.04	Low
Hoko Winter	747	-0.01	0.28	<0.01	Low
Quillayute-Bogachiel Winter	2,163	+0.01	0.55	0.09	Low
Dickey Winter	418	-0.00	0.49	0.06	Low
Sol Duc Winter	5,110	+0.01	0.64	0.03	Low
Calawah Winter	3,773	+0.03	0.70	0.07	Low
Goodman Creek Winter	374	+0.06	0.76	0.05	Low
Hoh Winter	2,268	-0.01	0.41	0.03	Low
Queets Winter	7,840	+0.01	0.60	0.06	Low
Clearwater Winter [1]					
Lower Quinault-Quinault Lake Winter [1]					
Quinault Winter	1,201	+0.01	0.76	<0.01	Low

[1] Analysis not yet completed.

7.3.3 Southwest Washington

Synopsis. The status of populations in the Southwest Washington region varies by sub-region. **In** *2002 SaSI assessed 100% of the populations in the Willapa sub-region as Healthy, 57% of the populations in the Grays Harbor subregion as Healthy, and 0% of the populations in the Columbia Mouth sub-region as Healthy. Smolt-to-adult return (SAR) rates appear to have declined for populations in the Columbia Mouth sub-region from the mid-1980s to the mid-1990s. SAR rates subsequently increased in both the Grays Harbor and Columbia Mouth subregions as did the escapement of many natural populations. Escapement increased by an average of 116% in 1999 through 2004 relative to the previous 5-year period. Population viability analysis suggests that two out of the three populations in the Columbia Mouth subregion remain at a relatively High risk of extinction.*

ESA Status

Populations of steelhead in the Southwest Washington ESU are currently not listed under the ESA.

Pre-Settlement and Current Production Potential

The current and pre-settlement production potential for many winter steelhead populations in Grays Harbor are available through a study funded by the Chehalis Basin Fisheries Task Force, WDFW, U.S. Fish and Wildlife Service, and the U.S. Army Corps of Engineers (Mobrand Biometrics 2003) (Table 7-7). Relative to pre-settlement conditions, the production potential of winter steelhead populations in Grays Harbor are predicted to have been reduced by an average of 68% (range 60% to 74%). The smallest reduction (60%) is predicted for the Hoquiam Winter population and the largest reduction (76%) for the South Bay Winter population.

The production potential of steelhead populations in the Columbia Mouth sub-region was assessed during the development of the Lower Columbia recovery plan (LCRFB 2004). An average of 56% of the production potential is predicted to have been lost relative to pre-settlement conditions for populations in this region.

No predictions are available for the production potential of steelhead populations in the Willapa Bay subregion.

SaSI Assesment and Short-term Trends

Population status as rated by SaSI in 2002 varies by subregion (Table 7-8)(see Appendix 7-A for population specific assessments). All of the winter populations in the Willapa subregion were rated as Healthy, 57% in the Grays Harbor subregion were Healthy, but 100% of the populations in the Columbia Mouth subregion were rated as Depressed. No populations were rated as Critical in any of the subregions. Population status of the two summer populations in the Grays Harbor subregion could not be assessed because of the lack of abundance data.

The escapement of populations of winter steelhead in the Southwest Washington region increased by an average of 116% in 1999 through 2004 relative to the previous 5 years (Table 7-9 and Fig. 7-5). An increase in the average escapement occurred for 15 of the 16 winter steelhead populations for which escapement is monitored. The exception was the Hoquiam Winter population, for which the escapement was below the goal in every year from 1999 through 2003. However, the escapement increased to 950 fish in 2004, or 500 fish greater than the escapement goal.

Table 7-7. Current and pre-settlement production potential (equilibrium adult abundance) for winter and summer populations of steelhead in the Lower Columbia River region.

Population	Current	Pre-settlement	Percent lost
Grays Habor			
Chehalis Winter	1,731	6,719	74%
Hoquiam Winter	223	561	60%
Humptulips Winter	884	2,437	64%
Satsop Winter	983	2,903	66%
Skookumchuck-Newaukum Winter	993	3,357	70%
South Bay Winter	37	152	76%
Wishkah Winter	184	508	64%
Wynoochee Winter	389	1,356	71%
Grays Harbor Average			68%
Columbia Mouth			
Mill-Abernathy-Germany Winter	838	1,936	57%
Elochoman-Skamokawa Winter	416	936	56%
Grays Winter	1,072	2,399	55%
Columbia Mouth Average			56%
Southwest Washington Average			65%

Table 7-8. Status of winter steelhead populations in the Southwest Washington region.

Sub-region	Number of Populations	Populations with unknown status	Populations with known status			
			Number	Healthy (%)	Depressed (%)	Critical (%)
Grays Harbor	8	1	7	4 (57%)	3 (43%)	0 (0%)
Willapa	6	0	6	6 (100%)	0 (0%)	0 (0%)
Columbia Mouth	3	0	3	0 (0%)	3 (100%)	0 (0%)
All	17	1	16	10 (63%)	6 (37%)	0 (0%)

Table 7-9. Short-term trend in escapement for winter steelhead populations in the Southwest Washington region. Base years are 1994 through 1998; years for comparison are 1999 through 2004.

Sub-region	Number of Populations	Populations without spawner data	Populations with spawner data			
			Number	Increasing (%)	Unchanged (%)	Decreasing (%)
Grays Harbor	8	1	7	6 (86%)	0 (0%)	1 (14%)
Willapa	6	0	6	6 (100%)	0 (0%)	0 (0%)
Columbia Mouth	3	0	3	3 (100)	0 (0%)	0 (0%)
All	17	1	16	15 (94%)	0 (0%)	1 (6%)

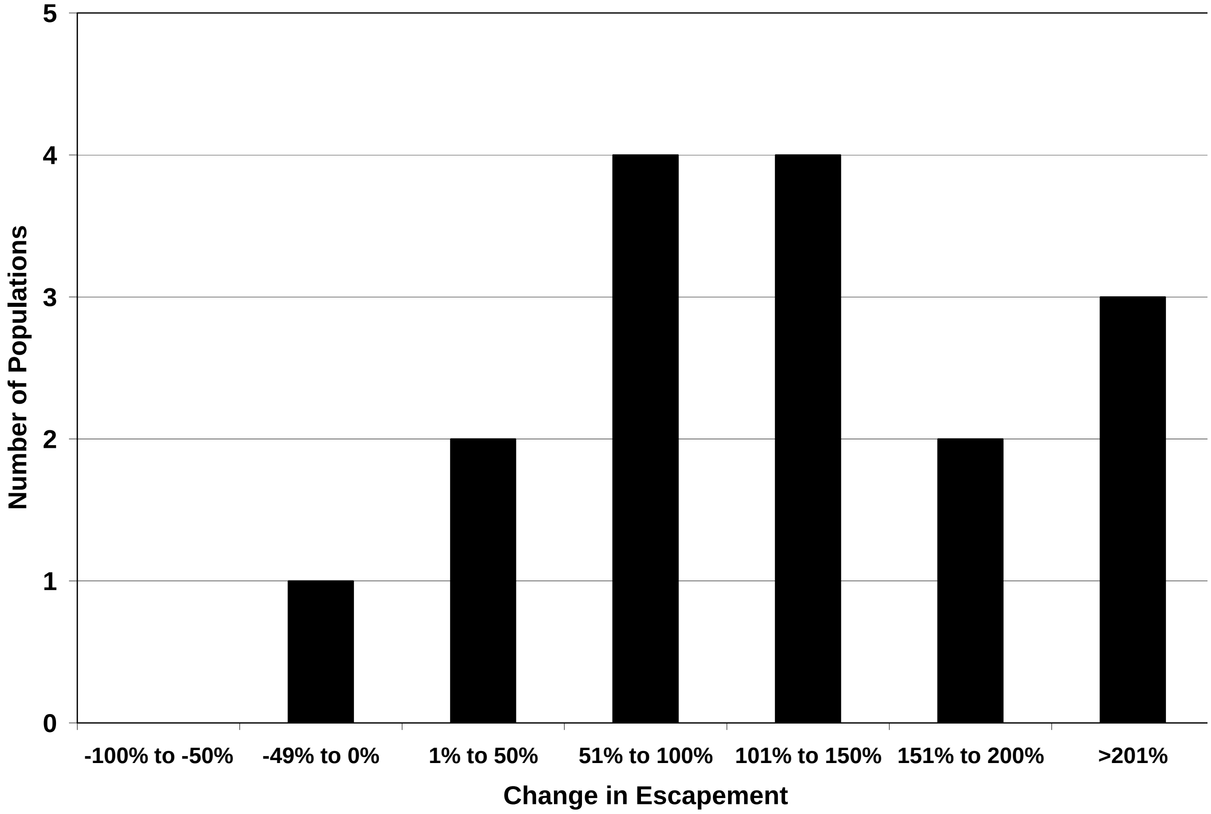

Figure 7-5. Change in the average escapement for populations of steelhead in the Southwest Washington region in 1999 through 2004 relative to the average escapement in 1993 through 1998.

Smolt-to-Adult Return

Indices for the smolt-to-adult survival rate could be estimated for winter steelhead smolts released into the Elochoman River and the Humptulips River (Fig. 7-6). The index for the Elochoman River showed a declining trend for smolts entering the ocean from 1985 through 1995. The SAR index increased after 1995 but generally remained below levels observed prior to 1994.

The time span of the data series for winter steelhead smolts released into the Humptulips River is limited to ocean entry in the years 1992 through 2002. The limited data available suggest that SAR rates were also low during the mid-1990s, but increased in the years 2000 through 2003.

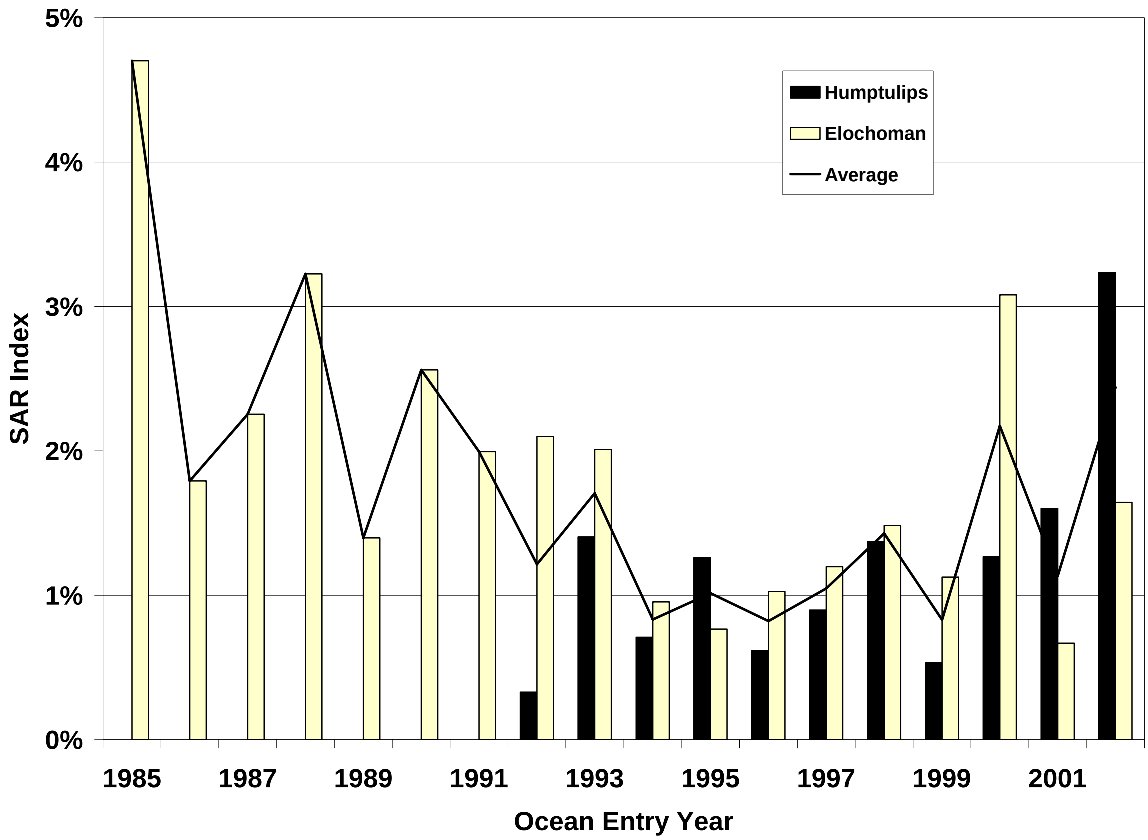

Figure 7-6. Average SAR survival indices for summer and winter steelhead smolts released into the Elochoman and Humptulips rivers.

Population Viability Analysis

Population viability analyses are critically dependent upon correctly identifying population structure. As discussed in Chapter 5 (Population Identification), greater uncertainty exists in the population structure in regions that have not been systematically reviewed by a Technical Recovery Team or agency staff. The results from the population viability analysis described below should be considered preliminary until that review is completed.

The population growth rate was estimated for 16 populations with a time series of at least 8 years of escapement data or indices of escapement (Table 7-10). The estimated growth rate was positive for 14 of the 16 populations, and for no population did the statistical test of the null hypothesis ($H_0 : \mu \geq 0$)result in a p-value of less than 0.10.

The percentage of the populations in each region with a relative risk of extinction that was not Low varied between the sub-regions. All seven populations analyzed in the Grays Harbor region were assessed to have Low risk; one of six populations in the

Willapa sub-region was assessed as relatively High risk; and two of three populations in the Columbia Mouth sub-region were assessed as High risk.

Table 7-10. Growth rate, p-value for statistical test ($H_0 : \mu \geq 0$), estimated process error ($\hat{\tau}^2$), and relative risk of extinction for populations of steelhead in the Southwest Washington region.

Population	Last Escapement	Growth Rate		$\hat{\tau}^2$	Relative risk
		Estimate	p-value		
Grays Harbor					
Chehalis Winter	3,704	-0.00	0.48	0.32	Low
Hoquiam Winter	950	-0.03	0.11	0.01	Low
Humptulips Winter	3,884	+0.00	0.52	0.05	Low
Satsop Winter	4,519	+0.01	0.55	0.04	Low
Skookumchuck/Newaukum Winter	2,438	+0.05	0.82	0.05	Low
Wishkah Winter	1,102	+0.00	0.50	0.19	Low
Wynoochee Winter	3,162	+0.06	0.70	0.23	Low
Willapa Bay					
Bear River Winter	461	+0.10	0.66	0.33	High
Naselle Winter	1,856	+0.10	0.97	<0.01	Low
Nemah Winter	908	+0.14	0.72	0.36	Low
North/Smith Winter	898	+0.14	0.74	0.32	Low
Palix Winter	226	+0.12	0.77	<0.01	Low
Willapa Winter	1,560	+0.15	0.75	0.31	Low
Columbia Mouth					
Mill-Abernathy-Germany Winter	446	+0.16	0.58	0.28	High
Elochoman-Skamokawa Winter	768	+0.15	0.56	0.26	High
Grays Winter	1,132	+0.06	0.68	0.22	Low

7.3.4 Lower Columbia River

Synopsis. The current production potential of steelhead populations in the Lower Columbia River region is predicted to have been reduced by an average of 77% relative to the production potential that existed prior to European settlement. Reductions in production potential, coupled with low smolt-to-adult return (SAR) rates in the early to mid-1990s, drove many populations to low levels of abundance. Since that time, SAR rates have increased and escapement in 1998 through 2004 increased by an average of 90% relative to the previous 5-year period. The 2002 SaSI assessment characterized 11% of the populations as Healthy, 89% as Depressed, and 0% as Critical. Through population viability analysis we identified two populations (Coweeman Winter and NF/Mainstem Toutle Winter) as High risk; all remaining populations for which the analysis was feasible were categorized as a relatively low risk. The Lower Columbia River ESU was listed as Threatened under the ESA in 1998 (63 FR 13347) and relisted in 2005 (71 FR 834).

ESA Status

The Lower Columbia River ESU was listed as Threatened under the ESA in 1998 (63 FR 13347). A NOAA Biological Review Team reassessed the status of the ESU in 2005 and 73% of the votes cast by team members supported the conclusion that the ESU was likely to become endangered in the foreseeable future (Good et al. 2005). NOAA Fisheries relisted the Lower Columbia River DPS as Threatened in 2005 (71 FR 834).

Pre-Settlement and Current Production Potential

The current and pre-settlement production potential for many populations of steelhead was computed during the development of the Lower Columbia recovery plan (LCFRB 2004) (Table 7-11). These analyses were updated for this report using the most recent assessment of historical conditions in the mainstem Columbia River and life history trajectories. The percent of the pre-settlement production potential predicted to have been lost ranged from 52%-95% for winter steelhead populations and 48%-64% for summer steelhead populations. The average loss for summer steelhead populations (53%) was less than for winter steelhead populations (73%). An average of 69% of the pre-settlement production potential is predicted to have been lost for the populations analyzed in the Lower Columbia River region.

SaSI Assessment and Short-Term Trends

The 2002 SaSI assessment rated one population (Kalama Winter) as Healthy and eight populations (89%) as Depressed (Table 7-12)(see Appendix 7-A for population specific assessments). No populations were rated as Critical. Status assessments were not possible for 47% of the populations because of the lack of a consistent time series of abundance data.

Table 7-11. Current and pre-settlement production potential (equilibrium adult abundance) for winter and summer populations of steelhead in the Lower Columbia River region.

Population	Current	Pre-settlement	Percent lost
Lower Columbia Winter			
Cispus Winter	324	1,487	78%
Tilton Winter	124	1,635	92%
Upper Cowlitz Winter	867	3,888	78%
Lower Cowlitz Winter	311	1,820	83%
Toutle Winter [1]	932	5,292	82%
Coweeman Winter	609	1,431	57%
Kalama Winter	395	876	55%
NF Lewis Winter	298	5,860	95%
EF Lewis Winter	558	1,557	64%
Salmon Winter	61	327	81%
Washougal Winter	428	1,366	69%
Lower Gorge Winter	230	477	52%
Wind Winter	67	212	68%
Lower Columbia Summer			
Kalama Summer	613	1,117	45%
EF Lewis Summer	156	429	64%
Washougal Summer	555	1,066	48%
Wind Summer	1,088	2,404	55%
Lower Columbia Average			
Winter			73%
Summer			53%
Winter and Summer			69%

[1] Mainstem/NF Toutle, Green, and South Fork Toutle populations aggregated for this analysis.

Recent trends in the escapement of populations of steelhead in the Lower Columbia ESU are generally positive (Table 7-12 and Fig. 7-7)(see Appendix 7-A for population specific assessments). The escapement of steelhead increased by an average of 90% in 1999-2004 relative to the prior five years for the populations for which estimates of escapement were available. The average escapement increased for nine populations (82%), was unchanged for one population (9%), and decreased for one population (9%). Escapement for the latter population, Kalama Summer, has been increasing in recent years. The escapement of the Kalama Summer steelhead population dropped from a high of 2,283 fish in 1993 to a low of 140 fish in 2000. Since that time, escapements have begun to increase, and were 817 and 632 in 2003 and 2004, respectively.

Table 7-12. Status of steelhead populations in the Lower Columbia River region.

Run timing	Number of Populations	Populations with unknown status	Populations with known status			
			Number	Healthy (%)	Depressed (%)	Critical (%)
Summer	5	3	2	0 (0%)	2 (100%)	0 (0%)
Winter	12	5	7	1 (14%)	6 (86%)	0 (0%)
All	17	8	9	1 (11%)	8 (89%)	0 (0%)

Table 7-13. Short-term trend in escapement for steelhead populations in the Lower Columbia River region. Base years are 1994 through 1998; years for comparison are 1999 through 2004.

Run timing	Number of Populations	Populations without spawner data	Populations with spawner data			
			Number	Increasing (%)	Unchanged (%)	Decreasing (%)
Summer	5	1	4	2 (50%)	1 (25%)	1 (25%)
Winter	12	5	7	7 (100%)	0 (0%)	0 (0%)
All	17	6	11	9 (82%)	1 (9%)	1 (9%)

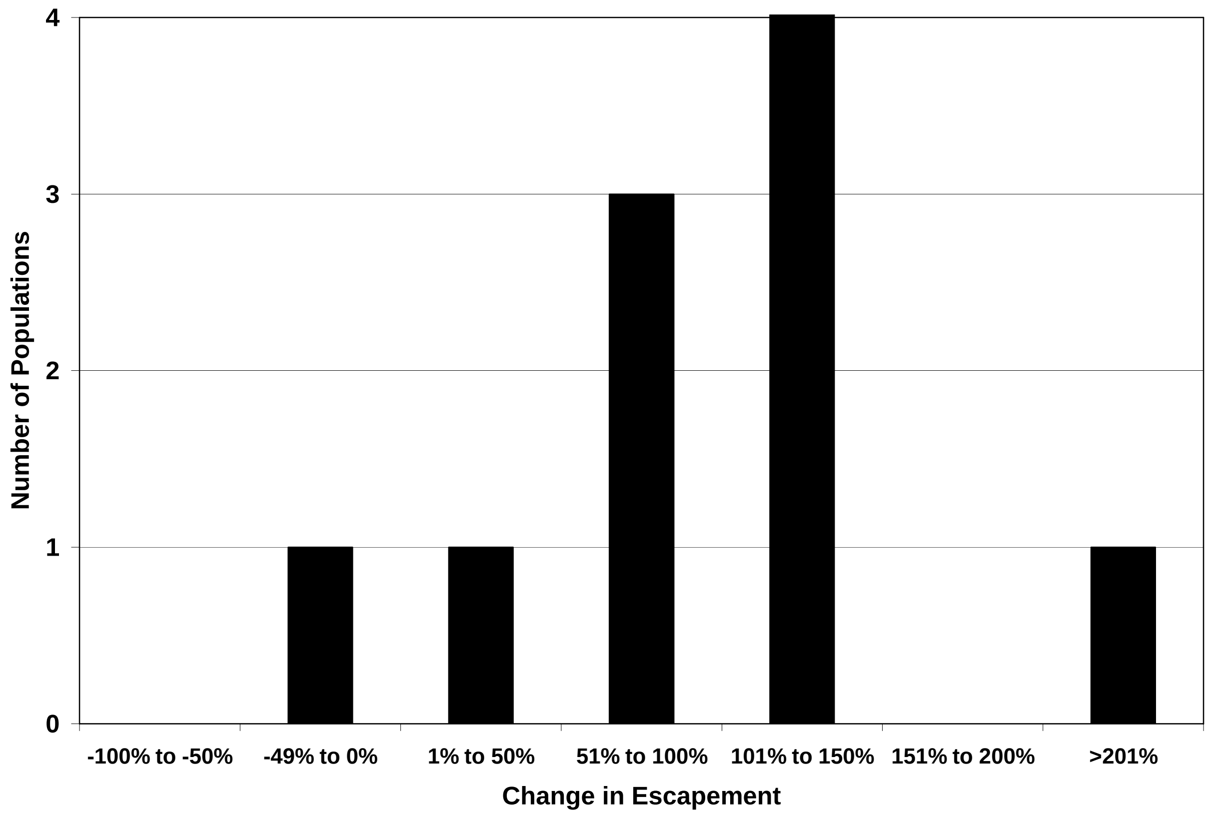

Figure 7-7. Change in the average escapement for populations of steelhead in the Lower Columbia region in 1999 through 2004 relative to the average escapement in 1993 through 1998.

Smolt to Adult Return

Indices of the average smolt to adult survival rates for summer and winter steelhead smolts released from four hatchery programs (summer and winter steelhead in the Washougal and Kalama rivers) in the Lower Columbia region showed a similar pattern (Fig. 7-8). Indices were relatively high for smolts that entered the ocean from 1980 through 1990, generally declined until 1995, and increased until 2000. The SAR indices for 1996 were less than 25% of the values estimated for smolts entering the ocean in the late 1980s.

Two analyses suggest that natural population abundance was also affected by the environmental conditions controlling the SAR indices for hatchery smolts. The most direct evidence is from the natural populations of summer and winter steelhead in the Kalama River. A SAR index can be computed for eight years in the period from 1978 through 2001 when a smolt trap was in operation. Since smolts originating from the summer and winter parents cannot be visually distinguished, the SAR index was computed for the total adult return of summer and winter steelhead divided by the total summer and winter smolt production. Substantial annual variability exists, but average SAR rates for 5-year periods showed a trend similar to the SAR for hatchery-origin smolts (Fig. 7-9).

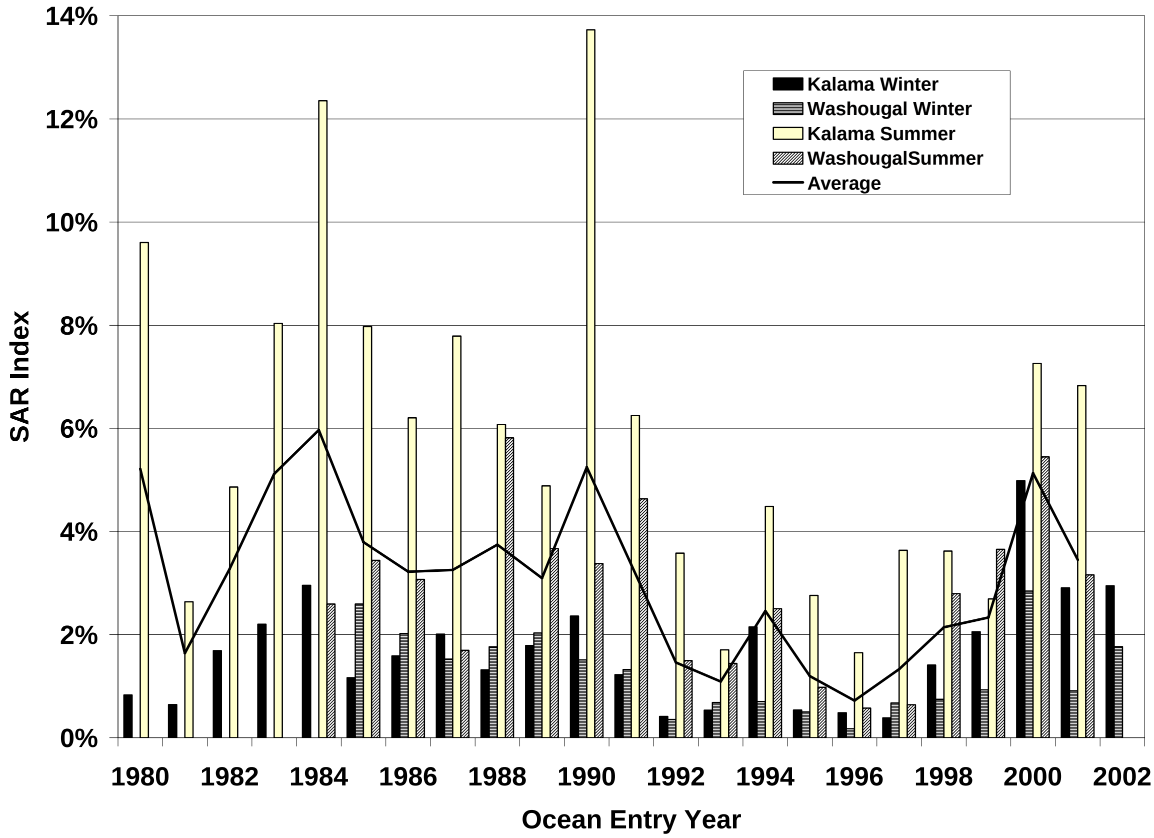

Figure 7-8. Average SAR survival indices for summer and winter steelhead smolts released into the Kalama and Washougal rivers.

Stock-recruit analyses also suggest that both the number of spawners and the hatchery SAR index were linked to the number of recruits in the subsequent generation. Although the length of data series was often short, the SAR index for hatchery-origin smolts was a significant predictor ($p < 0.10$) of recruits produced per spawner for 8 of the 10 natural populations with a time series of escapement and recruitment data (Table 7-14).

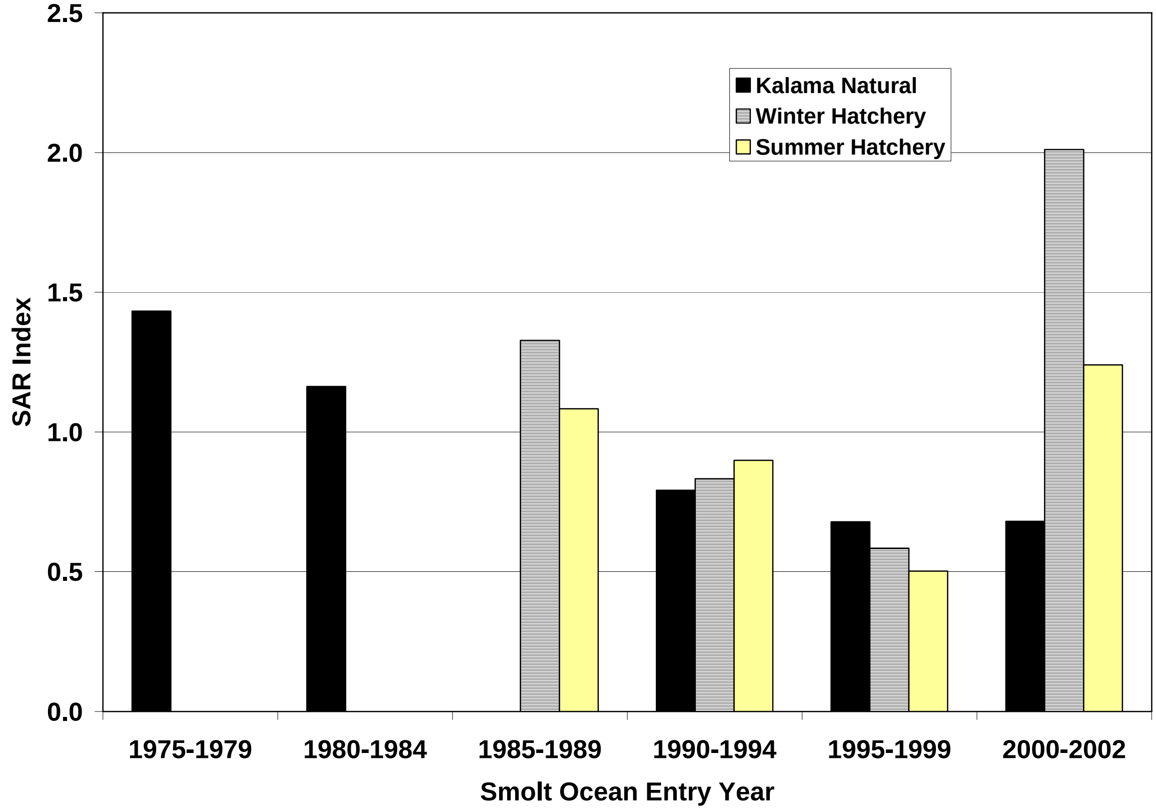

Figure 7-9. Average SAR indices for 5-year periods for the aggregate of natural-origin summer and winter steelhead in the Kalama River and for the hatchery-origin SAR indices for Lower Columbia hatchery programs.

Table 7–14. Number of observations and p-values for regression model and two predictor variables (spawners and SAR index) for recruits per spawner produced for natural-origin populations of steelhead in the Lower Columbia region.

Population	Observations	Regression	Spawners	SAR Index
Coweeman Winter	10	1.37E-02	5.70E-03	4.72E-01
Mainstem/NF Toutle Winter	12	4.72E-04	1.40E-04	1.26E-02
Green Winter	14	4.45E-04	1.26E-01	1.22E-04
SF Toutle Winter	17	1.25E-02	7.33E-03	5.96E-02
Kalama Summer	18	1.19E-04	9.95E-05	2.06E-03
Kalama Winter	18	7.53E-06	2.95E-05	3.04E-04
EF Lewis Winter	12	1.53E-01	6.89E-01	4.15E-01
Washougal Summer	14	1.05E-04	3.33E-05	8.02E-05
Washougal Winter	8	1.66E-02	1.85E-02	2.43E-02
Wind Summer	11	1.08E-03	1.39E-03	5.36E-03

Population Viability Analysis

Population growth rate could be estimated for 11 populations[1] with a time series of at least 9 years of escapement data or indices of escapement (Table 7-15). The estimated growth rate was positive for 8 of the 11 populations, and for no population did the statistical test of the null hypothesis ($H_0 : \mu \geq 0$) result in a p-value of less than 0.10.

The relative risk of extinction was estimated for 7 populations with a time series of at least 8 years of escapement data. In general, confidence intervals for the probability of extinction were wide at the 5, 20, and 100-year time horizons (Appendix 7-B). Two populations, Coweeman Winter and Mainstem/NF Toutle Winter, were assessed at a relatively high level of risk based on an estimated extinction probability that exceeded 20% in 20 years. The remaining five populations all were assessed to have a relatively low risk of extinction.

Table 7-15. Growth rate, p-value for statistical test ($H_0 : \mu \geq 0$), estimated process error ($\hat{\tau}^2$), and relative risk of extinction for populations of steelhead in the Lower Columbia River region.

Population	Last Escapement	Growth Rate		$\hat{\tau}^2$	Relative Risk
		Estimate	p-value		
Coweeman Winter	722	-0.02	0.47	0.55	High
Mainstem/NF Toutle Winter	249	+0.18	0.86	0.36	High
Green Winter	256	-0.06	0.32	0.25	[1]
SF Toutle Winter	1,212	+0.14	0.85	0.38	Low
Kalama Summer	632	+0.01	0.55	0.32	Low
Kalama Winter	2,400	+0.04	0.71	0.16	Low
EF Lewis Summer	673	+0.13	0.92	0.15	Low
EF Lewis Winter	1,298	+0.08	0.77	0.23	NA
Washougal Summer	607	+0.12	0.84	0.25	Low
Washougal Winter	1,114	+0.15	>0.99	<0.01	[1]
Wind Summer	930	-0.00	0.48	0.14	[1]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.

[1] Unlike the Puget Sound, Olympic Peninsula, and Southwest Washington regions, information on population structure in this region has been reviewed and populations identified by a technical recovery team. See Chapter 5 for a description.

7.3.5 Middle Columbia River

Synopsis. The potential production of steelhead has been reduced by an average of 87% relative to pre-settlement conditions for populations of steelhead in the Klickitat, Yakima, and Walla Walla sub-basins. The 2002 SaSI assessment characterized the Touchet Summer and an aggregate of the Yakima populations as Depressed. The status of other populations was not determined because of the lack of an adequate time series of abundance information. Short-term trends in escapement for the Middle Columbia River region are mixed. An index of escapement for the Touchet population decreased by 43% in 1999 through 2004 relative to the prior five years. In contrast, the short-term trend of the escapement for the aggregate of four Yakima populations is positive, with an increase in the average escapement of 225%. The Middle Columbia River DPS was listed as Threatened under the ESA in 1999 (64 FR 14517) and relisted in 2005 (71 FR 834).

ESA Status

The Middle Columbia River ESU was listed as Threatened under the ESA in 1999 (64 FR 14517). A NOAA Biological Review Team reviewed the status of the ESU in 2005. A slight majority (51%) of votes cast by the team concluded that the ESU was likely to become endangered in the foreseeable future; a minority (49%) concluded that that the ESU was not likely to become endangered in the foreseeable future (Good et al. 2005). NOAA Fisheries relisted the Middle Columbia River DPS as Threatened in 2005 (50 FR 834).

Pre-Settlement and Current Production Potential

A substantial part of the production potential for populations in the Middle Columbia River region is predicted to have been lost (Table 7-16). Relative to pre-settlement conditions, 95% or more of the production potential is predicted to have been lost for steelhead populations in the Yakima and Walla Walla rivers. Degradation of habitat in the Klickitat subbasin has been ameliorated to some extent by the construction of fish passage facilities at Castille Falls.

SaSI Assessment and Short-Term Trends

The assessment of populations in this ESU is complicated by the evolving identification of populations. In the 2002 SaSI assessment, WDFW identified a single population of steelhead in the Yakima subbasin. The ICTRT subsequently identified three populations (ICTRT 2003) and ultimately concluded that four populations (Satus, Toppenish, Naches, and Upper Yakima) existed (McClure and Cooney, pers. comm.). WDFW and the Yakama Nation have not yet completed a status assessment for each of the newly defined populations. As an interim measure for this report, we have reported the SaSI assessment and percent change in escapement for the aggregate Yakima population and provided a summary of additional information on each of the newly identified four populations.

Table 7-16. Current and pre-settlement production potential (equilibrium adult abundance) for populations of steelhead in the Middle Columbia River region.

Population	Current	Pre-settlement	Percent lost
Klickitat [1]	1,248	2,171	43%
Naches	510	24,701	98%
Satus	488	9,694	95%
Toppenish	340	7,604	96%
Upper Yakima	715	40,710	98%
Walla Walla	774	15,529	95%
Average			87%

[1] Current production potential includes area above Castille Falls; pre-settlement includes only area below Castille Falls because it was impassable before fish passage facilities were built.

Limited data exists to assess the status of populations in the Middle Columbia River region (Table 7-17) (see Appendix 7-A for population specific assessments). Abundance data is not available for the Klickitat Summer and Rock Creek Summer populations; only data for the Oregon component of the Walla Walla Summer population is available. Both of the remaining two populations (Yakima and Touchet) were rated as Depressed in the 2002 SaSI assessment.

Table 7-17. Status of steelhead populations in the Middle Columbia River region.

Run timing	Number of Populations	Populations with unknown status	Populations with known status			
			Number	Healthy (%)	Depressed (%)	Critical (%)
Summer	5 [1]	3	2	0 (0%)	2 (100%)	0 (0%)

[1] Includes an aggregate Yakima population rather than the four populations identified by the ICTRT. See text for discussion.

Short-term trends in escapement for the Middle Columbia River region are mixed (Table 7-18)(see Appendix 7-A for population specific assessments). An index of escapement for the Touchet population decreased by 43% in 1999 through 2004 relative to the prior five years. In contrast, the short-term trend of the escapement for the aggregate of four Yakima populations is positive, with an increase in the average escapement of 225%. Indices of abundance also have increased for two of the populations in the Yakima subbasin. Redd counts in Satus Creek increased by 36% for the same time period (1994 excluded from the base years because of limited visibility) and the count of natural-origin steelhead at the Roza Dam (Upper Yakima population) increased by 261% (Freudenthal et al. 2005).

Table 7-18. Short-term trend in escapement for steelhead populations in the Middle Columbia River region. Base years are 1994 through 1998; years for comparison are 1999 through 2004.

Run timing	Number of Populations	Populations without spawner data	Populations with spawner data			
			Number	Increasing (%)	Unchanged (%)	Decreasing (%)
Summer	5	3	2	1 (50%)	0 (0%)	1 (50%)

[1] Includes an aggregate Yakima population rather than the four populations identified by the ICTRT. See text for discussion.

Smolt to Adult Return

Estimates of SAR survival indices are available for summer steelhead with CWTs released into the Touchet and Walla Walla rivers (WDFW 2005a). Since 1988 the SARs indices for the Touchet River have ranged from 0.6% to 2.7% with an average of 1.5%. SAR indices for summer steelhead released into the Walla Walla River have been similar, with an overall average of 1.6% (Fig. 7-10).

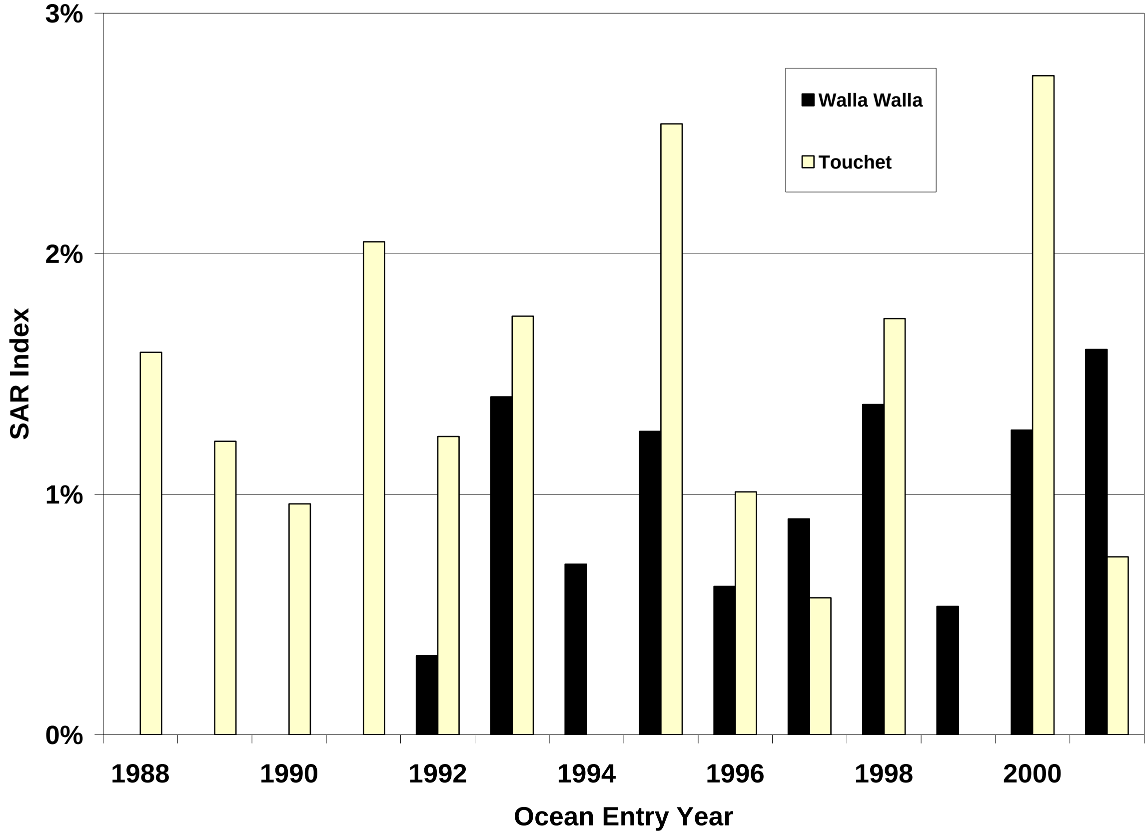

Figure 7-10. SAR survival indices for steelhead smolts released into the Touchet and Walla Walla rivers.

Population Viability Analysis

An estimate of population growth rate is currently available for the Touchet Summer population[2] (Table 7-19). The population is estimated to be declining and a test of the null hypothesis of a nonnegative growth rate is rejected at $\alpha \leq 0.10$. The relative extinction risk could not be estimated for any populations in the Middle Columbia River region because of the lack of estimates of escapement.

[2] Unlike the Puget Sound, Olympic Peninsula, and Southwest Washington regions, information on population structure in this region has been reviewed and populations identified by a technical recovery team. See Chapter 5 for a description.

Table 7-19. Growth rate, p-value for statistical test ($H_0 : \mu \geq 0$), estimated process error ($\hat{\tau}^2$), and relative risk of extinction for populations of steelhead in the Middle Columbia River region.

Population	Last Escapement	Growth Rate		$\hat{\tau}^2$	Relative Risk
		Estimate	p-value		
Touchet Summer	[1]	-0.04	0.07	<0.01	[1]
Satus Summer	[1]	[2]	[2]	[2]	[1]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.
[2] Analysis not yet completed.

7.3.6 Upper Columbia River

Synopsis. Steelhead populations in the Wenatchee, Entiat, Methow, and Okanogan sub-basins are predicted to have lost an average of 98% of the productive potential that existed prior to European settlement. The Wenatchee and an aggregate Okanogan-Methow population were each assessed as Depressed by SaSI in 2002; an adequate time series of escapement data was not available to assess the remainder of the populations in this region. Smolt-to-adult return indices appear to have increased slightly to an average of 1.5% in the most recent four years, and the average escapement for the period 1999 through 2004 increased by approximately 280% relative to the prior five-year period. The Upper Columbia River ESU was listed as Endangered under the ESA in 1997 (62 FR 43937) and relisted as Threatened in 2005 (71 FR 834).

ESA Status

The Upper Columbia River ESU was listed as Endangered under the ESA in 1997 (62 FR 43937). A NOAA Biological Review Team reviewed the status of the ESU in 2005. A slight majority of votes (54%) of the team supported the conclusion that the ESU was in danger of extinction; a minority (44%) concluded that that the ESU was likely to become endangered in the foreseeable future (Good et al. 2005). NOAA Fisheries relisted the Upper Columbia River DPS as Threatened in 2005 (71 FR 834).

Pre-Settlement and Current Production Potential

Predictions of the pre-settlement and current production potential of steelhead populations have been developed in conjunction with the preparation of a recovery plan for Upper Columbia steelhead. The predicted production potential lost relative to conditions prior to European settlement ranges from 94% to 100% for the four populations for which the analysis has been completed (Table 7-20).

Table 7-20. Current and pre-settlement production potential (equilibrium adult abundance) for populations of steelhead in the Upper Columbia River region.

Population	Current	Pre-settlement	Percent lost
Wenatchee	317	5,363	94%
Entiat	0	[1]	100%
Methow	207	11,323	98%
Okanogan	29	2,152	99%
Average			98%

[1] A population of steelhead is believed to have existed in the Entiat River historically. However, model analyses have not been conducted with historical conditions throughout the entire life history pathway for the historical population.

SaSI Assessment and Short-Term Trends

The assessment of populations in the Upper Columbia ESU is complicated by the evolving identification of populations. The 2002 SaSI identified a single Methow-Okanogan population, but this was subsequently split by the ICTRT (2003) into a Methow and an Okanogan population. As an interim measure for this report, we have reported the SaSI assessment and percent change in escapement for the aggregate Methow-Okanogan population. No abundance data is available for the Crab Creek population.

The status and trends in escapement (Wenatchee and Methow-Okanogan) are similar for the two populations for which data are available. Both populations were rated as depressed in SaSI (Table 7-21), and the short term trends in escapement indices is positive (Table 7-22). Indices of escapement for the period 1999 through 2004 have increased by approximately 280% for both populations relative to the prior five-year period (see Appendix 7-A).

Table 7-21. Status of steelhead populations in the Upper Columbia River region.

Run timing	Number of Populations	Populations with unknown status	Populations with known status			
			Number	Healthy (%)	Depressed (%)	Critical (%)
Summer	4 [1]	2	2	0 (0%)	2 (100%)	0 (0%)

[1] Includes an aggregate Methow-Okanogan population rather than the two separate populations identified by the ICTRT. See text for discussion.

Table 7-22. Short-term trend in escapement for steelhead populations in the Upper Columbia River region. Base years are 1994 through 1998; years for comparison are 1999 through 2004.

Run timing	Number of Populations	Populations without spawner data	Populations with spawner data			
			Number	Increasing (%)	Unchanged (%)	Decreasing (%)
Summer	4 [1]	2	2	2 (100%)	0 (0%)	0 (0%)

[1] Includes an aggregate Methow-Okanogan population rather than the two separate populations identified by the ICTRT. See text for discussion.

Smolt to Adult Return

Estimates of the smolt-to-adult return (SAR) index have been computed for summer steelhead released from the Wells Hatchery (WDFW 2002; C. Snow, pers. comm.). The SAR index declined from a peak value of 7.5% for smolts entering the ocean in 1982 to a low of 0.3% for 1992 and 1993 (Fig. 7-10). SAR indices are estimated in the last 4 years (1999 through 2002) to an average of 1.5%.

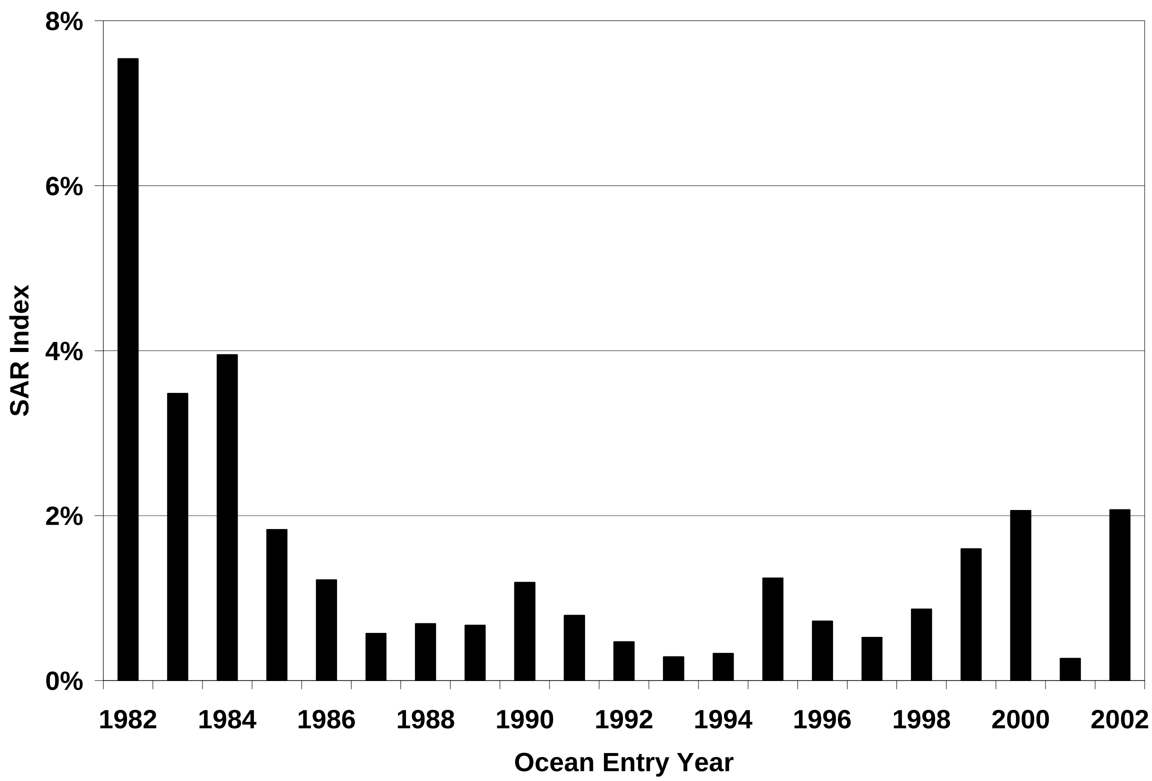

Figure 7-11. SAR survival indices for summer steelhead smolts released from the Wells Hatchery.

Population Viability Analysis

The population growth rate could be estimated for two populations[3] or population aggregates with a time series of at least 8 years of escapement or indices of escapement data (Table 7-23). The Wenatchee population had an estimated growth rate that was negative but a statistical test failed to reject the null hypothesis of a

[3] Unlike the Puget Sound, Olympic Peninsula, and Southwest Washington regions, information on population structure in this region has been reviewed and populations identified by a technical recovery team. See Chapter 5 for a description.

nonnegative growth rate. The estimated growth rate for the aggregate Methow-Okanogan populations was positive and the relative risk of extinction was characterized as Low.

Table 7-23. Growth rate, p-value for statistical test ($H_0 : \mu \geq 0$), estimated process error ($\hat{\tau}^2$), and relative risk of extinction for populations of steelhead in the Upper Columbia River region.

Population	Last Escapement	Growth Rate		$\hat{\tau}^2$	Relative Risk
		Estimate	p-value		
Wenatchee	[1]	-0.01	0.47	0.35	[1]
Methow-Okanogan [2]	945	+0.03	0.62	0.17	Low

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.
[2] Analysis is for aggregate of Methow and Okanogan populations as estimated from counts at Wells Dam.

7.3.7 Snake River Basin

Synopsis. The production potential of the Asotin Creek, Tucannon, Lower Grande, and Joseph populations is predicted to have been reduced by an average of 84% from pre-settlement conditions. The two populations for which estimates of escapement indices are available, Tucannon and Asotin, were both rated as Depressed in the 2002 SaSI status assessment. Estimates of the population growth rate for both populations are negative, although the escapement index for the Asotin population did increase by 87% (101 fish) in 1999 through 2004 relative to the prior five years. Smolt-to-adult return (SAR) indices do not appear to have a temporal trend, and averaged 1.1% for smolts entering the ocean from 1983 through 2002. The Snake River Basin ESU was listed as Threatened under the ESA in 1997 and relisted in 2005 (71 FR 834)

ESA Status

The Snake River Basin ESU was listed as Threatened under the ESA in 1997 (62 FR 43937). A NOAA Biological Review Team reviewed the status of the ESU in 2005. A majority of votes (74%) of the team supported the conclusion that the ESU was likely to become endangered in the foreseeable future (Good et al. 2005). NOAA Fisheries relisted the Snake River Basin DPS as Threatened in 2005 (71 FR 834).

Pre-Settlement and Current Production Potential

The pre-settlement and current production potential of steelhead populations in the Washington component of the Snake River Basin were assessed during the development of recovery plans for the Lower Snake and Grande Ronde. Relative to pre-settlement conditions, an average of 84% of the production potential has been lost for the Asotin, Tucannon, Lower Grande Ronde, and Joseph steelhead populations (Table 7-24).

Table 7-24. Current and pre-settlement production potential (equilibrium adult abundance) for populations of steelhead in the Snake River Basin region.

Population	Current	Pre-settlement	Percent lost
Asotin	103	8,275	99%
Tucannon	283	12,268	98%
Lower Grande Ronde	1,117	1,969	43%
Joseph	407	6,201	95%
Average			84%

SaSI Assessment and Short-Term Trends

The two populations for which escapement data are available (Tucannon and Asotin Creek) were both rated Depressed in the 2002 SaSI assessment (Table 7-25)(see Appendix 7-A for population specific assessments). Indices of escapement increased by an average of 46% in 1999 through 2004 relative to the five prior years (Table 7-26), but this increase occurred primarily for the Asotin population. The average escapement index for the Tucannon population differed by only six fish (5%) between the two time periods.

Table 7-25. Status of steelhead populations in the Snake River Basin region.

Run timing	Number of Populations	Populations with unknown status	Populations with known status			
			Number	Healthy (%)	Depressed (%)	Critical (%)
Summer	4	2	2	0 (0%)	2 (100%)	0 (0%)

Table 7-26. Short-term trend in escapement for steelhead populations in the Snake River Basin region. Base years are 1994 through 1998; years for comparison are 1999 through 2004.

Run timing	Number of Populations	Populations without spawner data	Populations with spawner data			
			Number	Increasing (%)	Unchanged (%)	Decreasing (%)
Summer	4	2	2	1 (50%)	1 (50%)	0 (0%)

Smolt to Adult Return

Smolt-to-adult return indices were computed for releases of Lyons Ferry stock released directly into the Snake River from Lyons Ferry Hatchery (WDW 2005b). The indices appear to be more variable, and perhaps lower, in recent years (Fig. 7-12). The SAR indices ranged from 0.26 to 2.33 for smolts entering the ocean from 1983 through 2002,with an average SAR index of 1.14%.

Population Viability Analysis

A time series of at least eight years of escapement data or indices of escapement were available for two populations[4], the Asotin and the Tucannon (Table 27). The estimated population growth rate was negative for each of the populations. The null hypothesis that the population growth rate was nonnegative was rejected for the Tucannon population but not the Asotin population.

Population viability analysis could not be conducted for any of the populations because of the lack of a time series of escapement data of at least eight years in duration.

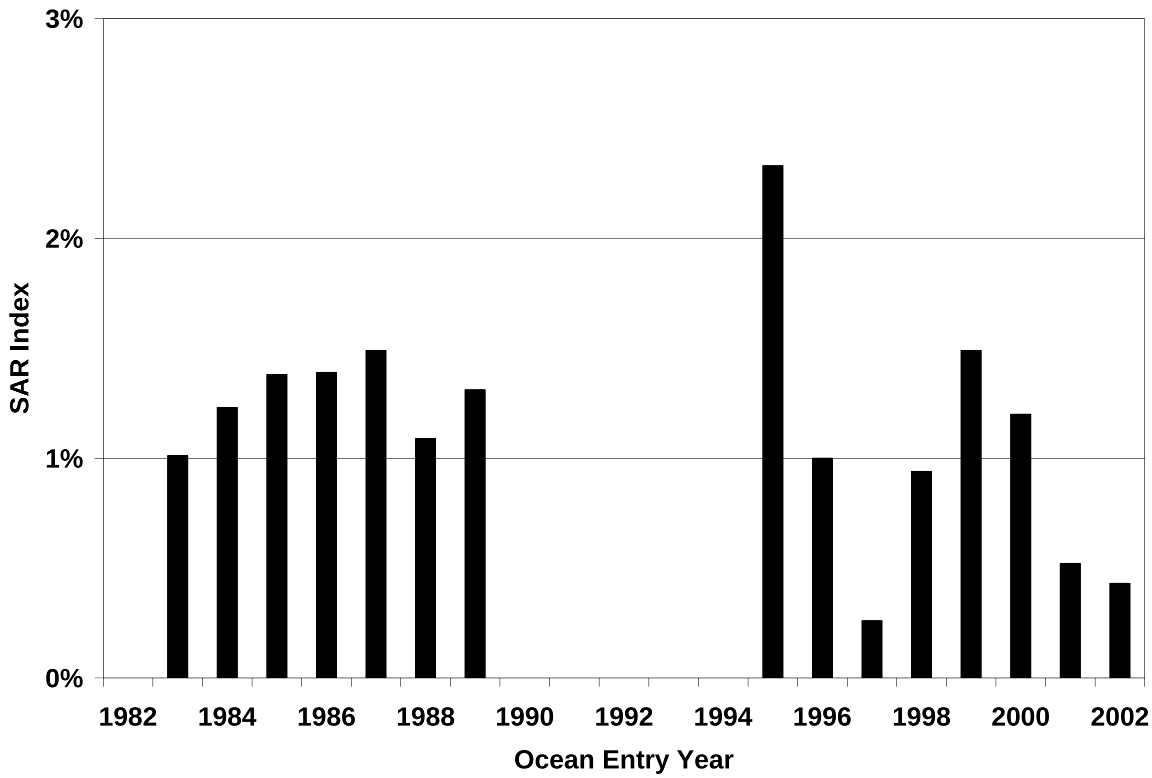

Figure 7-12. SAR survival indices for summer steelhead smolts released from the Lyons Ferry Hatchery.

[4] Unlike the Puget Sound, Olympic Peninsula, and Southwest Washington regions, information on population structure in this region has been reviewed and populations identified by a technical recovery team. See Chapter 5 for a description.

Table 7-27. Growth rate, p-value for statistical test ($H_0 : \mu \geq 0$), estimated process error ($\hat{\tau}^2$), and relative risk of extinction for populations of steelhead in the Snake River Basin region.

Population	Last Escapement	Growth Rate		$\hat{\tau}^2$	Relative Risk
		Estimate	p-value		
Asotin	[1]	-0.01	0.45	0.18	[1]
Tucannon	[1]	-0.11	0.04	0.21	[1]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.

7.4 Discussion

The productive potential of steelhead populations has been substantially reduced in many regions of Washington State relative to the potential that existed prior to European settlement (Table 7-27). Although the specific habitat factors contributing to this decline vary by watershed, the consequences are evident – fishing opportunities for naturally produced steelhead are limited and populations in many regions of Washington are at a significant risk of extinction.

Table 7-27. Mean loss in potential production and percent of populations Healthy in each region of Washington.

Region	Mean loss in potential production (# populations assessed)	% Populations Healthy (# populations assessed)
Upper Columbia River	98% (4)	0% (2)
Middle Columbia River	87% (6)	0% (2)
Snake River Basin	84% (4)	0% (2)
Lower Columbia River	69% (16)	11% (9)
Puget Sound	[1] (1)	20% (25)
Southwest Washington	68% (11)	65% (16)
Olympic Peninsula	NA (0)	92% (13)

[1] Assessment has been completed only for the Nisqually Winter population where 57% of the production potential is predicted to have been lost.

The effects of the loss in potential production were accentuated in the mid 1990s for many populations in western Washington by a sharp decline in smolt-to-adult survival rates (Fig. 7-13). In the Lower Columbia River region for example, the average smolt-to-adult survival rate in the years 1995 through 1999 was less than 50% of the survival rate from 1985 through 1989. Similar changes have been observed for steelhead populations in British Columbia, and reductions in ocean productivity have been hypothesized as a potential explanation for the geographic coherence of the observations (Welch et al. 2000).

Variations in the magnitude and duration of the decline in smolt-to-adult survival rates exist between regions in Washington. This may simply result from anomalies in the data used to compute the indices or differences in population migration patterns and ocean productivity. The reduction in smolt-to-adult survival rates for Puget Sound populations, in particular, appears to have been both greater in magnitude and duration than other populations. Unlike the other three coastal regions, survival rates in Puget Sound do not appear to have increased in 2000 and 2001. A similar, prolonged reduction in the abundance of steelhead in southern British Columbia has been attributed to a reduction in marine survival (Ward 1999; Welch 2000).

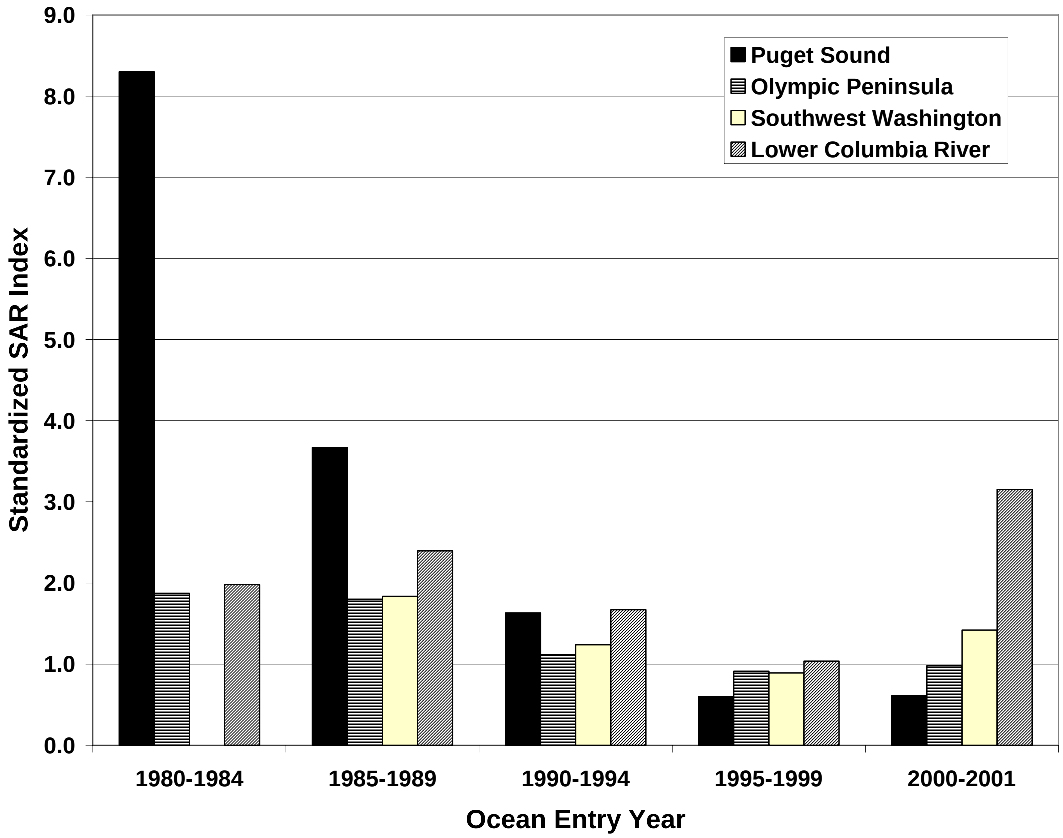

Fig. 7-13. Average smolt-to-adult survival rates (standardized to the average for ocean entry years 1992 through 1995) for four coastal regions of Washington.

Improvements in smolt-to-adult survival rates may have contributed to the increase in escapement observed for many populations in recent years (Fig. 7-14). The average escapement for steelhead populations throughout Washington increased by 48% in the years 1999 though 2004 relative to the prior 5 years. The response was not consistent across regions, with the escapement of populations in the Puget Sound region decreasing by an average of 23%. In some cases, such as the Skagit River, escapements exceeded the management goal during 1995 through 1998, and an increase in escapement would not be expected. However, even for populations for which the escapement has increased in recent years, the return of steelhead to former levels of abundance will require substantial improvements in the productivity of the habitat.

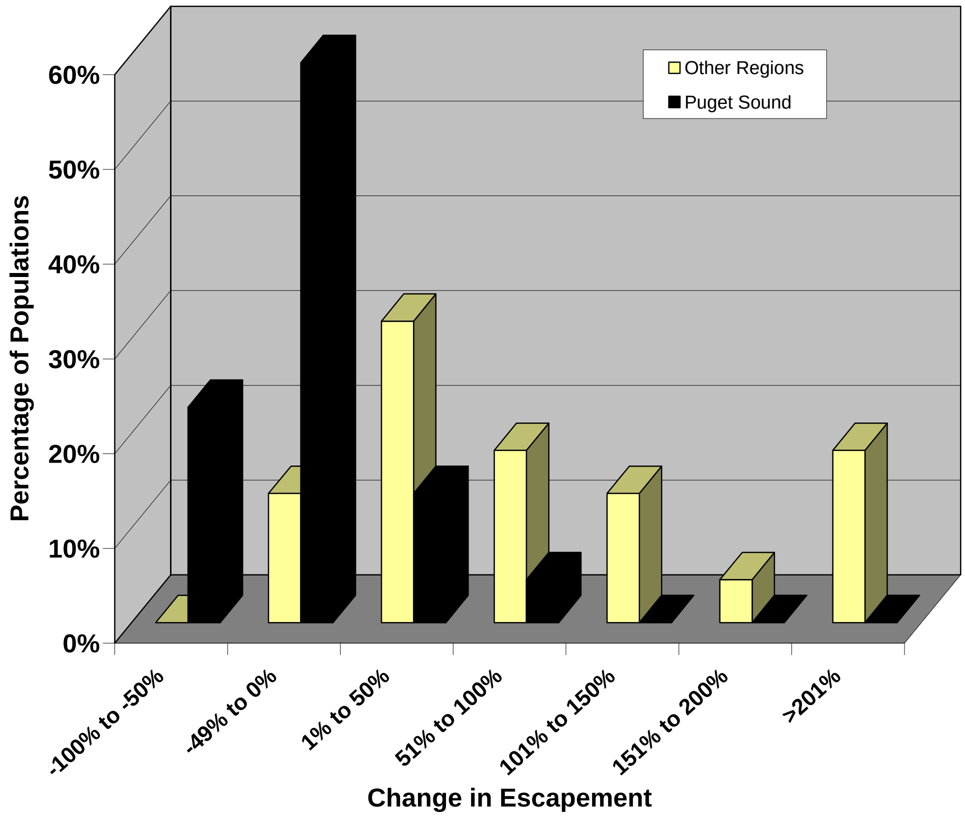

Figure 7-14. Change in the average escapement for populations of steelhead in the Puget Sound region and the remainder of the state in 1999 through 2004 relative to the average escapement in 1993 through 1998.

7.5 Findings and Recommendations

Finding 7-1. The inability to monitor the escapement of populations introduces significant uncertainty and risk into the management of steelhead in Washington. The status of 47% of the steelhead populations could not be rated because of the lack of a time series of escapement or other abundance data.

> *Recommendation 7-1.* Prioritize monitoring, solicit funding, develop alternative estimation methods and sample designs, and enlist the assistance of other organizations to increase the percentage of populations assessed on a regular basis.

Finding 7-2. Degradation of riverine, estuarine, and nearshore habitat has resulted in the loss of an average of 83% of the potential production of the 42 steelhead populations assessed in Washington. Improvements in habitat protection measures and restoration of degraded or inaccessible habitat are essential to assure the long-term viability of natural populations of steelhead in Washington.

> *Recommendation 7-2.* Ensure that the technical expertise of WDFW is available to local planning groups and governments to assist in the identification of the habitat factors reducing the viability of steelhead populations. Provide web access to map-based information on the stream reaches of high value for protection and restoration actions.
>
> *Recommendation 7-3.* Enhance the ability of local planning groups to effectively pursue new funding opportunities and efficiently use existing fund sources by developing a web application that identifies a schedule of priority habitat protection areas and restoration projects.
>
> *Recommendation 7-4.* Through a recently initiated project to evaluate the feasibility of developing habitat conservation plans for the Hydraulic Project Approval (HPA) program, and for WDFW owned and managed wildlife areas: a) assess the potential impacts of WDFW land management activities on steelhead; b) assess the potential impacts of HPA-permitted activities on steelhead; c) evaluate potential conservation measures to fully mitigate for adverse impacts resulting from HPA permitted activities; d) identify HPA activities that will require new research or monitoring efforts to assess impacts and potential mitigation measures; and e) develop tools and strategies to facilitate the monitoring, tracking, and adaptive management of HPA activities.
>
> *Recommendation 7-5.* Develop and implement a consistent method for using remote sensing data to monitor trends in the status of habitat. Many planning forums require or would benefit from information about the status and trends of habitat across Washington State. This coarse-scale information, in various forms, is widely available through remote sensing but little effort has been given to standardizing products to meet multiple stakeholder needs simultaneously or in providing a template upon which future updates can made.

Finding 7-3. The status of steelhead populations varies substantially across Washington. Over 90% of the populations in the Olympic Peninsula region and over 60% in the Southwest Washington region were rated as "Healthy". However, less than 20% of the steelhead populations were rated as "Healthy" in the five remaining regions of Washington. Yet, recent data does suggest some reason for optimism. Possibly due to improved marine conditions, the average escapement for steelhead populations throughout Washington increased by 48% in the years 1999 through 2004 relative to the prior 5 years.

Finding 7-4. Population viability analysis identified thirteen populations of steelhead with the potential for substantive conservation concerns. The population viability analysis (PVA) conducted for this paper can be used as a tool to filter data and identify populations with a potential conservation concern. However, additional information is needed to fully assess the risk of extirpation. PVA can be misleading, particularly where population structure is uncertain or, as in the case with this analysis, the potential contribution of rainbow trout to population performance was not considered.

> *Recommendation 7-6.* Reassess the status of all populations in Washington on a 4 to 8 year cycle to assure that opportunities for early action are not missed. Use PVA to filter spawner abundance data and, for populations identified to have a potential conservation concern, broaden the analysis to evaluate the contribution of rainbow trout to population viability, the previous performance of the population, and factors affecting population status.

> *Recommendation 7-7.* Annually monitor and review the status of populations at risk, identify limiting factors, and assess the effectiveness of management actions. If necessary, implement new programs to address limiting factors, and potentially initiate "rescue programs" like kelt reconditioning or hatchery supplementation to conserve natural populations until limiting factors are addressed.

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Appendix Table 7-A1. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapment, and SaSI status for populations in the Puget Sound region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Nooksack Basin				
Dakota Creek Winter[1]				Unknown
Mainstem/NF Nooksack Winter[1]				Unknown
MF Nooksack Winter[1]				Unknown
SF Nooksack Summer [1]				Unknown
SF Nooksack Winter[1]				Unknown
Samish Winter	841	930	+11%	Healthy
Skagit Basin				
Mainstem Skagit/Tribs Winter	7,172	5,963	-17%	Depressed
Finney Creek Summer [1]				Unknown
Sauk Summer[1]				Unknown
Sauk Winter[1]				Unknown
Cascade Summer[1]				Unknown
Cascade Winter[1]				Unknown
Stillaguamish Basin				
Stillaguamish Winter	1,238	627	-49%	Depressed
Deer Creek Summer[2]	12	10	-17%	Depressed
SF Stillaguamish Summer[1]				Unknown
Canyon Creek Summer[1]				Unknown
Snohomish Basin				
Snohomish/Skykomish Winter	4,092	1,842	-55%	Depressed
Pilchuck Winter	1,485	720	-51%	Depressed
NF Skykomish Summer[1]				Unknown
SF Skykomish Summer	909	936	+3%	Healthy
Tolt Summer	212	151	-29%	Healthy
Snoqualmie Winter	1,952	1,099	-44%	Depressed
Lake Washington Basin				
Lake Washington Winter	327	69	-79%	Critical
Duwamish/Green Basin				
Green Summer[3]	69	28	-59%	Depressed
Green Winter	2,249	1,827	-19%	Healthy
Puyallup Basin				
Mainstem Puyallup Winter	206	112	-46%	Depressed
White (Puyallup) Winter	332	320	-4%	Depressed
Carbon Winter	756	380	-50%	Depressed

Appendix Table 7-A1 (continued). Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Puget Sound region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
South Sound Basin				
Nisqually Winter	849	438	-48%	Depressed
Eld Inlet Winter[1]				Unknown
Totten Inlet Winter[1]				Unknown
Hammersley Inlet Winter[1]				Unknown
Case/Carr Inlets Winter[1]				Unknown
East Kitsap Winter[1]				Unknown
Hood Canal				
Dewatto Winter	24	24	0	Depressed
Tahuya Winter	103	164	58%	Depressed
Union Winter[1]				Unknown
Skokomish Summer[1]				Unknown
Skokomish Winter	415	273	-34%	Depressed
Hamma Hamma Winter	19	81	340%	Depressed
Duckabush Summer[1]				Unknown
Duckabush Winter[1,4]				Depressed
Dosewallips Summer[1]				Unknown
Dosewallips Winter	61	83	36%	Depressed
Quilcene/Dabob Bays Winter[4]				Unknown
Strait of Juan de Fuca				
Discovery Bay Winter[5]	72	71	-2%	Healthy
Sequim Bay Winter[1]				Unknown
Dungeness Summer[1]				Unknown
Dungeness Winter[4]				Depressed
Morse Cr/Independent Tribs. Winter	126	103	-18%	Depressed
Elwha Summer[1]				Unknown
Elwha Winter[1]				Unknown

[1] There are no adequate abundance data for this stock.

[2] Data are juveniles/100 m^2.

[3] Data are sport catch estimates.

[4] There are insufficient data for the 1994-1998 period.

[5] Data are total run size estimates (catch + escapement).

Appendix Table 7-A2. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Olympic Peninsula region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Strait of Juan de Fuca				
Salt Creek/Independents Winter	159	153	-4%	Healthy
Lyre Winter[1]				Unknown
Pysht/Independents Winter	285	362	+27%	Healthy
Clallam Winter[1]				Unknown
Hoko Winter	613	693	13%	Healthy
Sekiu Winter[1]				Unknown
Sail Winter[1]				Unknown
Sooes/Ozette Basin				
Sooes/Waatch Winter[1]				Unknown
Ozette Winter[1]				Unknown
Quillayute Basin				
Quillayute/Bogachiel Summer[1]				Unknown
Quillayute/Bogachiel Winter	2,133	2,629	+23%	Healthy
Dickey Winter	512	578	+13%	Healthy
Sol Duc Summer[1]				Unknown
Sol Duc Winter	5,712	5,049	-12%	Healthy
Calawah Summer[1]				Unknown
Calawah Winter	3,824	4,275	+12%	Healthy
Hoh Basin				
Goodman Creek Winter	232	296	+28%	Healthy
Mosquito Creek Winter[1]				Unknown
Hoh Summer[1]				Unknown
Hoh Winter	2,689	2,604	-3%	Healthy
Kalaloch Basin				
Kalaloch Winter[1]				Unknown
Queets Basin				
Queets Summer[1]				Unknown
Queets Winter	1,375	1,448	+5%	Healthy
Clearwater Summer[1]				Unknown
Clearwater Winter	1,287	1,323	+3%	Healthy
Raft Basin				
Raft Winter[1]				Unknown

Appendix Table 7-A2. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Olympic Peninsula region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Quinault Basin				
Quinault/Lake Quinault Winter	1,477	783	-47%	Depressed
Quinault Summer[1]				Unknown
Quinault Winter	1,375	1,448	+5%	Healthy
Moclips/Copalis Basins				
Moclips Winter[1]				Unknown
Copalis Winter[1]				Unknown

[1] There are no adequate abundance data for this stock.

Appendix Table 7-A3. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Southwest Washington region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Grays Harbor				
Chehalis Summer[1]				Unknown
Chehalis Winter	1,635	2,678	+64%	Healthy
Humptulips Summer[1]				Unknown
Humptulips Winter	1,322	2,279	+72%	Depressed
Hoquiam Winter	491	425	-13%	Depressed
Wishkah Winter	367	730	+99%	Healthy
Wynoochee Winter	1,715	2,160	+26%	Healthy
Satsop Winter	2,566	3,193	+24%	Depressed
Skookumchuck/Newaukum Winter	861	1,803	+109%	Healthy
South Bay Winter[1]				Unknown
Willapa Bay				
North/Smith Cr Winter	427	1,155	+170%	Healthy
Willapa Winter	410	1,427	+248%	Healthy
Palix Winter	70	154	+119%	Healthy
Nemah Winter	313	1,018	+225%	Healthy
Naselle Winter	908	1,610	+77%	Healthy
Bear River Winter	193	583	+201%	Healthy
Columbia Mouth				
Grays Winter	415	939	+126%	Depressed
Skamokawa Cr/Elochoman Winter	258	571	+121%	Depressed
Mill-Abernathy-Germany Creeks Winter[2]	129	361	+181%	Depressed

[1] There are no adequate abundance data for this stock.

[2] Data are for Abernathy and Germany creeks only; there are no data for Mill Creek.

Appendix Table 7-A4. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Lower Columbia region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Cowlitz Winter[1]				Unknown
Coweeman Winter	214	432	+102%	Depressed
Mainstem/NF Toutle Winter	170	257	+52%	Depressed
Green Winter	132	210	+59%	Depressed
SF Toutle Winter	388	794	+105%	Depressed
Kalama Summer	752	425	-44%	Depressed
Kalama Winter	747	1,163	+56%	Healthy
NF Lewis Summer[1]				Unknown
NF Lewis Winter[1]				Unknown
EF Lewis Summer	184	441	+139%	Unknown
EF Lewis Winter	186	608	+228%	Depressed
Salmon Creek Winter[1]				Unknown
Washougal Summer	135	294	+117%	Unknown
Washougal Winter	163	585	+260%	Depressed
Lower Gorge Winter[1]				Unknown
Wind Summer	506	516	+2%	Depressed
Wind Winter[1]				Unknown

[1]There are no adequate abundance data for this stock.

Appendix Table 7-A5. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Middle Columbia River region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Klickitat Summer-Winter[1]				Unknown
Rock Creek Summer[1]				Unknown
Walla Walla Summer[1]				Unknown
Touchet Summer	407	234	-43%	Depressed
Satus Creek Summer [2]	811	2,632	+225%	Depressed
Toppenish Creek Summer [2]				
Naches Summer [2]				
Upper Yakima Summer [2]				

[1] There are no adequate abundance data for this stock.
[2] A single Yakima population was identified in SaSI 2002 and only data collected at Prosser Dam, a location that includes returning adults of all four populations, have been collated and analyzed.

Appendix Table 7-A6. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Upper Columbia River region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Crab Creek[1]				Not Rated
Wenatchee[1]	499	1,919	+284%	Depressed
Entiat Summer[1]				Unknown
Methow [2]	174	664	+281%	Depressed
Okanogan [2]				

[1] There are no adequate abundance data for this stock.
[2] A single Methow-Okanogan population was identified in SaSI 2002 and data are currently available only for the constituent populations.

Appendix Table 7-A7. Average escapement in 1994 through 1998, 1999 through 2004, % change in escapement, and SaSI status for populations in the Snake River Basin region.

Population	Average escapement			Status
	1994-1998	1999-2004	% Change	
Tucannon	116	122	+5%	Depressed
Asotin Creek	123	230	+87%	Depressed
Lower Grande Ronde[1]				Not Rated
Joseph Creek[1]				Not Rated

[1]There are no adequate abundance data for this stock.

Appendix Table 7-B1. Population viability analysis for steelhead populations in the Puget Sound region.

Population	Last Escapement	$\hat{\mu}$	$S\hat{E}(\hat{\mu})$	$\hat{\tau}^2$	df	Extinction risk (95% confidence interval)		
						5-year	20-year	100-year
Samish Winter	930	+0.0569	1.1442E-01	3.2730E-01	16	0.02 [0.00, 0.20]	0.17 [0.01, 0.77]	0.35 [0.00, 1.00]
Skagit Winter	7,332	+0.0135	3.9006E-02	3.7476E-02	23	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]
Stillaguamish Winter	[1]	-0.0651	1.1717E-02	4.2958E-06	15	[1]	[1]	[1]
Snohomish-Skykomish Winter	2,188	+0.0227	6.6615E-02	1.0206E-01	19	0.00 [0.00, 0.00]	0.01 [0.00, 0.31]	0.11 [0.00, 1.00]
Pilchuck Winter	1336	+0.0436	9.0275E-02	1.8744E-01	19	0.00 [0.00, 0.04]	0.05 [0.00, 0.56]	0.19 [0.00, 1.00]
Tolt Summer	[1]	-0.0491	1.0431E-01	1.9998E-01	16	[1]	[1]	[1]
Snoqualmie Winter	708	-0.0260	4.0384E-02	3.4476E-02	19	0.00 [0.00, 1.00]	0.02 [0.00, 1.00]	0.67 [0.00, 1.00]
Lake Washington Winter	44	-0.1581	1.5344E-01	5.4149E-01	21	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]
Green Winter	2,383	+0.0198	3.6875E-02	3.3433E-02	25	0.00 [0.00, 0.23]	0.00 [0.00, 0.11]	0.00 [0.00, 1.00]
Mainstem Puyallup Winter	91	-0.0603	6.0299E-02	7.1917E-02	20	0.70 [0.34, 0.93]	0.93 [0.50, 1.00]	1.00 [0.54, 1.00]
White (Puyallup) Winter	184	-0.0136	7.7124E-02	1.3966E-01	23	0.22 [0.04, 0.57]	0.58 [0.10, 0.97]	0.85 [0.11, 1.00]
Carbon Winter	410	-0.0742	3.3152E-02	2.0121E-02	20	0.00 [0.00, 1.00]	0.33 [0.00, 1.00]	1.00 [0.26, 1.00]
Nisqually Winter	730	-0.0744	3.4261E-02	2.2903E-02	22	0.00 [0.00, 1.00]	0.10 [0.00, 1.00]	1.00 [0.13, 1.00]
Dewatto Winter	[1]	-0.0075	2.2063E-02	5.7832E-06	19	[1]	[1]	[1]
Tahuya Winter	[1]	+0.0144	6.7688E-02	9.9765E-02	22	[1]	[1]	[1]
Skokomish Winter	223	-0.0755	1.2673E-02	3.3952E-06	18	0.00 [1.00, 1.00]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]
Dosewallips Winter	[1]	+0.0311	3.5957E-02	5.8361E-06	7	[1]	[1]	[1]
Duckabush Winter	[1]	+0.0190	1.0647E-01	6.3545E-05	6	[1]	[1]	[1]
Discovery Bay Winter	40	-0.0319	5.7188E-02	8.0937E-02	26	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]	1.00 [1.00, 1.00]
Morse Creek-Independents Winter	121	-0.0102	2.0383E-02	5.5768E-03	17	0.00 [0.00, 0.14]	0.15 [0.00, 1.00]	0.83 [0.00, 1.00]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.

Appendix Table 7-B2. Population viability analysis for steelhead populations in the Olympic Peninsula region.

Population	Last Escapement	$\hat{\mu}$	$S\hat{E}(\hat{\mu})$	$\hat{\tau}^2$	df	Extinction risk (95% confidence interval)		
						5-year	20-year	100-year
Salt Creek-Independents Winter	170	-0.0351	2.0604E-02	8.5730E-06	9	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	1.00 [0.00, 1.00]
Pysht-Independents Winter	367	+0.0081	4.5925E-02	4.1045E-02	19	0.00 [0.00, 0.02]	0.04 [0.00, 0.60]	0.26 [0.00, 1.00]
Hoko Winter	747	-0.0120	2.0025E-02	4.4480E-03	18	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.04 [0.00, 1.00]
Quillayute-Bogachiel Winter	2,163	+0.0076	5.9351E-02	8.9891E-02	25	0.00 [0.00, 0.01]	0.01 [0.00,0.24]	0.17 [0.00, 1.00]
Dickey Winter	418	-0.0008	5.1010E-02	6.1355E-02	25	0.00 [0.00, 0.03]	0.09 [0.00,0.71]	0.46 [0.00, 1.00]
Sol Duc Winter	5,110	+0.0135	3.6612E-02	3.2909E-02	25	0.00 [0.00, 1.00]	0.00 [0.00,1.00]	0.00 [0.00, 1.00]
Calawah Winter	3,773	+0.0290	5.4274E-02	7.4728E-02	25	0.00 [0.00, 0.00]	0.00 [0.00, 0.05]	0.02 [0.00, 0.93]
Goodman Creek Winter	374	+0.0573	7.7343E-02	5.1776E-02	8	0.00 [0.00, 0.13]	0.01 [0.00, 0.81]	0.02 [0.00, 1.00]
Hoh Winter	2,268	-0.0081	3.3895E-02	2.8867E-02	25	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.09 [0.00, 1.00]
Queets Winter	7,840	+0.0125	4.9574E-02	5.9700E-02	24	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.02 [0.00, 1.00]
Clearwater Winter [1]								
Quinault-Lake Quinault Winter [1]								
Quinault Winter	1,201	+0.0090	1.2429E-02	2.5385E-03	25	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]

[1] Analysis not yet completed.

Appendix Table 7-B3. Population viability analysis for steelhead populations in the Southwest Washington region.

Population	Last Escapement	$\hat{\mu}$	$S\hat{E}(\hat{\mu})$	$\hat{\tau}^2$	df	Extinction risk (95% confidence interval)		
						5-year	20-year	100-year
Chehalis Winter	15,825	+0.0577	7.2197E-02	1.0946E-01	20	0.00 [0.00, 0.00]	0.00 [0.00, 1.00]	0.03 [0.00, 1.00]
Hoquiam Winter	950	-0.0331	2.5560E-02	9.3057E-03	19	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.78 [0.00, 1.00]
Humptulips Winter	3,884	+0.0022	4.5070E-02	4.8596E-02	24	0.00 [0.00, 1.00]	0.00 [0.00, 0.80]	0.05 [0.00, 0.99]
Satsop Winter	4,519	+0.0060	4.4852E-02	3.7243E-02	19	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.01 [0.00, 1.00]
Wynoochee Winter	3,162	+0.0577	1.0724E-01	2.3002E-01	19	0.00 [0.00, 0.02]	0.02 [0.00, 0.51]	0.11 [0.00, 1.00]
Bear River Winter	461	+0.0960	2.1556E-01	3.2597E-01	7	0.06 [0.00, 0.63]	0.21 [0.00, 1.00]	0.30 [0.00, 1.00]
Naselle Winter	1,856	+0.0981	4.1049E-02	2.5178E-05	7	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	0.00 [0.00, 1.00]
Nemah Winter	908	+0.1352	2.2211E-01	3.5718E-01	7	0.02 [0.00, 0.46]	0.09 [0.00, 0.98]	0.13 [0.00, 1.00]
North/Smith Winter	898	+0.1435	2.0592E-01	3.1486E-01	7	0.01 [0.00, 0.45]	0.06 [0.00, 0.95]	0.09 [0.00, 1.00]
Palix Winter	226	+0.1208	1.4977E-01	2.5567E-04	7	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]	0.00 [0.00, 1.00]
Willapa Winter	1,560	+0.1516	2.0469E-01	3.1034E-01	7	0.00 [0.00, 0.33]	0.03 [0.00, 0.95]	0.04 [0.00, 1.00]

Appendix Table 7-B4. Population viability analysis for steelhead populations in the Lower Columbia River region.

Population	Last Escapement	$\hat{\mu}$	$S\hat{E}(\hat{\mu})$	$\hat{\tau}^2$	df	Extinction risk (95% confidence interval)		
						5-year	20-year	100-year
Coweeman Winter	722	-0.0159	1.8134E-01	5.5195E-01	14	0.15 [0.01, 0.54]	0.50 [0.03, 0.98]	0.79 [0.05, 1.00]
Mainstem/NF Toutle Winter	249	+0.1751	1.5416E-01	3.5648E-01	14	0.14 [0.01, 0.56]	0.24 [0.02, 0.88]	0.26 [0.02, 1.00]
Green Winter	[1]	-0.0560	1.1466E-01	2.4803E-01	17	[1]	[1]	[1]
SF Toutle Winter	1,212	+0.1378	1.2952E-01	3.8582E-01	21	0.01 [0.00, 0.14]	0.08 [0.00, 0.65]	0.12 [0.00, 0.98]
Kalama Summer	632	+0.0140	1.0958E-01	3.2084E-01	26	0.06 [0.01, 0.28]	0.33 [0.02, 0.88]	0.61 [0.03, 1.00]
Kalama Winter	2,400	+0.0445	7.9111E-02	1.5818E-01	25	0.00 [0.00, 0.00]	0.01 [0.00, 0.32]	0.10 [0.00, 0.98]
EF Lewis Summer	673	+0.1285	1.3052E-01	1.4651E-01	8	0.00 [0.00, 0.19]	0.01 [0.00, 0.77]	0.02 [0.00, 1.00]
EF Lewis Winter	1,298	+0.0848	1.1372E-01	2.3278E-01	15	0.00 [0.00, 0.08]	0.04 [0.00, 0.66]	0.10 [0.00, 1.00]
Washougal Summer	607	+0.1209	1.1867E-01	2.4764E-01	17	0.01 [0.00, 0.19]	0.08 [0.00, 0.69]	0.11 [0.00, 0.99]
Washougal Winter	[1]	+0.1485	3.7174E-02	3.6057E-03	11	[1]	[1]	[1]
Wind Summer	[1]	-0.0047	1.0299E-01	1.4406E-01	13	[1]	[1]	[1]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.

Appendix Table 7-B5. Population viability analysis for steelhead populations in the Middle Columbia River region.

Population	Last Escapement	$\hat{\mu}$	$S\hat{E}(\hat{\mu})$	$\hat{\tau}^2$	df	Extinction risk (95% confidence interval)		
						5-year	20-year	100-year
Touchet Summer	[1]	-0.0358	2.2545E-02	1.0097E-05	12	[1]	[1]	[1]
Satus Summer	[1]	[2]	[2]	[2]	[2]	[1]	[1]	[1]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.

[2] Analysis not yet completed.

Appendix Table 7-B6. Population viability analysis for steelhead populations in the Upper Columbia River region.

Population	Last Escapement	$\hat{\mu}$	$S\hat{E}(\hat{\mu})$	$\hat{\tau}^2$	df	Extinction risk (95% confidence interval)		
						5-year	20-year	100-year
Wenatchee	[1]	-0.0105	1.4390E-01	3.5201E-01	16	[1]	[1]	[1]
Methow-Okanogan	945	+0.0296	9.8410E-02	1.6993E-01	17	0.00 [0.00, 0.08]	0.09 [0.00, 0.78]	0.29 [0.00, 1.00]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.

[2] Analysis not yet completed.

Appendix Table 7-B7. Population viability analysis for steelhead populations in the Snake Basin region.

Population	Last Escapement	$\hat{\mu}$	$S\hat{E}(\hat{\mu})$	$\hat{\tau}^2$	df	Extinction risk (95% confidence interval)		
						5-year	20-year	100-year
Asotin	[1]	-0.0139	1.0447E-01	1.7627E-01	12	[1]	[1]	[1]
Tucannon	[1]	-0.1088	5.6051E-01	4.2217E-02	15	[1]	[1]	[1]

[1] Estimate of escapement is an index so population viability could not be quantitatively analyzed.